THE UNIVERSITY OF ALBERTA

THE MORPHOLOGICAL CHARACTERS ASSOCIATED WITH FORAGE YIELD IN *BROMUS INERMIS* LEYSS. AND THEIR INHERITANCE

by

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Abstract

Eight clones of smooth bromegrass (Bromus inermis Leyss.) were selected from diverse sources and crossed in all possible combinations forming an 8x8 diallel. Plants of the F_1, the reciprocal crosses, and parents were grown in the field at Edmonton, Alberta. Observations were recorded for the sward characters height, vigor, spread, and yield at two harvests. Tillers were classified according to type, being nonelongated, elongated, and headed. Observations were made four times during the growing season on tiller density, individual tiller weight, weight and area of leaves, stems, and heads per tiller, leaf number per tiller, stem length, leaf to stem ratio, and standard leaf weight.

Results showed that individual tiller weight was positively related to leaf area and standard leaf weight within the tiller type. Nonelongated tiller number was positively related to number of leaves per nonelongated tiller, while elongated and headed tiller number increased with increasing stem length. High standard leaf weight, leaf to stem ratio, and leaf weight was negatively associated with the number of elongated and headed tillers. There were negative associations between the three tiller types.

Different tiller characters influenced yield of each of the two harvests. Characteristics of stems contribute more

to yield than leaves. Standard leaf weight was frequently negatively related to yield. Vigorous growth early in the season had a prominent effect on yield of the first harvest and was positively associated with the second harvest. Height at the time of each harvest was highly predictive of yield of the respective harvests. The taller plants yielded best.

General combining ability was significant for most of the characters observed. Fewer specific combining abilities were significant. Broad and narrow sense heritabilities were estimated. It was possible to identify sward and tiller characters which could be used in a selection index to develop the crop ideotype. On the basis of general combining ability effects the best yielding parent was a disease susceptible clone, and one of the poorest was disease resistant.

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I. INTRODUCTION

Smooth bromegrass, (*Bromus inermis* Leyss.) is widely grown in western Canada and Ontario as a hay crop with two harvests annually. The grass is winter hardy and drought tolerant, it is one of the most palatable grasses, grows well during midsummer when growth of most other grasses slows, and remains green longer than timothy (*Phleum pratense*). Bromegrass thrives on loam and sandy loam soils but heavy soils aggravate its tendency to become sod bound. Brome responds well to fertilization and mixes well with legumes partly because extra nitrogen counteracts the sod bound condition.

Some bromegrass varieties are better adapted to northern, and others to southern regions. The southern types are taller, coarse stemmed, more strongly creeping, and less leafy than northern varieties. The southern types turn green earlier in the season and remain green later in the fall than the northern types. They are more resistant than northern varieties to lodging and leaf spot diseases. Leaf spot diseases are a problem for bromegrass producers in western Canada and attempts have been made to develop resistant varieties.

The northern and southern type bromegrasses, and the disease resistant varieties represent a range of morphological types of bromegrass. It was the objective of this study to identify those characteristics of sward and tiller morphology which influenced yield of bromegrass, and

to describe their inter-relationship and inheritance.

II. LITERATURE REVIEW

1. Morphological Characters Associated with Yield of Forage Grasses

Investigators have been seeking to establish a relationship between characteristics of tiller morphology and yield of forage grasses and to describe their inheritance. The relationship between tiller characteristics is important since selection may be simplified by using correlations amongst tiller characteristics or a selection index approach. Selection could also be complicated by such associations.

Anslow, 1965 showed that rate of herbage production of timothy was closely related to size of tillers at harvest. Knight, 1970 associated yield of Dactylis glomerata with individual fertile tiller weight. Langer, 1959 showed that in timothy and meadow fescue (Festuca arundinacea), as the number of tillers declined, increases in dry matter became increasingly a function of unit tiller weight. Rogers and Lazenby, 1966, Anslow, 1967 and Thomson, Wright, and Rogers, 1973 related yield of Lolium perenne to tiller number. Glenday and Fejer, 1956 and Troughton, 1965 found number and size of tillers of equal importance in determining growth rates of perennial ryegrass. Thomson, Wright, and Rogers, 1973 observed a tendency for the relative importance of weight of individual fertile and sterile tillers to increase

towards the end of the season. Silsbury, 1966 suggested that plant weight increased due to tiller number during the vegetative phase and increasing individual tiller weight in the reproductive phase. Troughton, 1971 ascribed increases in the relative growth rate of the shoots of vegetative plants of Lolium perenne to increases in relative growth rate of both tiller number and tiller weight. As relative growth rate approached a maximum there was, however, less increase in the number of tillers and more increase in the weight of tillers. Langer, 1959 and Anslow, 1965 recorded maximum relative growth rate and crop growth rate of timothy and meadow fescue when flowering heads were emerging and Anslow, 1967 found higher rates of herbage production from perennial ryegrass swards which were allowed to flower. Knight, 1965 found that periods of maximum growth rate in cocksfoot varied according to inflorescence development. Jewiss, 1972 concluded that amounts of regrowth of Lolium temulentum and Phalaris tuberosa depend on both number and size of vegetative tillers present at the base of the reproductive tillers at the time of defoliation.

Tiller density of perennial and italian ryegrass (Lolium multiflorum), meadow and tall fescue (Festuca elatior), timothy, and orchardgrass declines from early spring to midsummer and then increases until autumn (Milthorpe and Ivins, 1966, Langer, 1959, Hunt and Brougham, 1966 and Taylor and Templeton, 1966). Hunt and Brougham, 1966 attributed the decline in tiller density of Lolium

multiflorum not to preponderant death of tillers, but rather to moderate tiller death and very low tiller initiation.

Some investigators (Langer, Ryle, and Jewiss, 1964 and Gillet, 1967) reported that inflorescence initiation reduced tiller initiation while others (Jewiss and McWilliam, 1970, Davies, 1969, and Jewiss, 1972) have shown that stem elongation restricts tillering. It was suggested (Langer, Ryle, and Jewiss, 1964, Williams, 1970, Hunt and Brougham, 1966, and Whittington and O´Brien, 1968) that competition contributed to the decline in tiller number. Cowling and Green, 1970 rejected this possibility, observing that all tillers in a sward were approximately the same size.

Brougham, 1956 and Donald and Black, 1958 associated increased grass crop growth rate with increasing photosynthetic area. Sheard and Winch, 1966 found forage growth rate increased until almost complete light interception. Wilson and McGuire, 1961 obtained highest forage yield when only 2% of the incident light reached the base of the sward. Thomson, Wright, and Rogers, 1973 and Cooper and Edwards, 1960 recommended selection for high optimum leaf area index. Taylor and Templeton, 1966 found overall leaf area index related to average dry matter accumulation in orchard grass, but during certain periods little or no relationship existed. Anslow, 1965 found crop growth rate unrelated to photosynthetic area. He suggested other factors besides leaf area index which affect the crop

growth rate. These were the arrangement of leaves, the interaction of sward structure and carbon dioxide diffusion, leaf turnover in the crop, and variation in the role of assimilation of an individual leaf during its life. Sheehy and Cooper, 1973, Rhodes, 1973, and Nelson, Asay and Horst, 1975 suggested that canopy architecture was as important as net carbon dioxide exchange of individual leaves in determining crop productivity. Leafe, Stiles and Dickinson, 1974 proposed that leaf arrangement on the culm might account for lower net carbon dioxide exchange of vegetative tillers of *Lolium perenne* as compared to reproductive tillers. Rhodes, 1972 demonstrated higher yield from *Lolium perenne* when incident light was spread over a larger photosynthetic area. He concluded that area for area comparisons of leaf areas were not adequate to describe their relationship to yield since canopy structure is important in determining photosynthetic exposure.

The importance of rate of leaf turnover in the sward was recognized by Hunt, 1965 and Hunt and Brougham, 1966 who reported that leaf loss through senescence was one of the major determinants of yield. Simon, Davies, and Troughton, 1972 found that greater losses due to death and decay in swards occurred when cutting height is increased and that this may account for the failure to see increases in production.

The contribution of a leaf to increasing dry weight of

the plant depends upon the balance between its photosynthesis and respiration. Anslow, 1967, Begg and Wright, 1964, Hopkinson, 1964, Pearce, 1966, Alburquerque, 1967, and Jewiss and Woledge, 1967 reported declining net assimilation rate with increasing age of leaves. Pearce, Brown, and Blaser, 1965, and Brown and Blaser, 1968 found that shading leaves decreased their photosynthetic ability. Some authors have maintained that because of these limitations on photosynthetic ability, at high leaf area indices leaves become parasitic, respiring more photosynthate than they contribute. There is evidence however (Brown and Blaser, 1968 and Alburquerque, 1967) that respiration decreases as shading increases. Ludwig, Saeki, and Evans, 1965, McCree and Troughton, 1966, King and Evans, 1967, and Wilfong, Brown, and Blaser, 1967 demonstrated that respiration decreases in the lower leaves, being dependent upon substrate supply rather than light. Lower leaves have been shown by loss of weight not to act as metabolic sinks, suggesting that the respiratory load of a crop is not proportional to leaf area (Davidson and Donald, 1958, Watson, 1958, Wilfong, Brown, and Blaser, 1967 and Williams, Loomis, and Lepley, 1965). Wilson and Cooper, 1970 associated increasing net carbon dioxide exchange and net assimilation rate of <u>Lolium perenne</u> with smaller mesophyll cells. Leaf size and photosynthetic rate were negatively correlated because larger leaves have larger cells and there is a negative relationship between mesophyll cell size and

rate of photosynthesis per unit leaf area (Cooper and Trickey, 1971, Wilson and Cooper, 1967, 1969, and Rhodes, 1972). Rhodes, 1973 did however find small cell size associated with slower leaf growth and lower yield.

Stems, especially the lower portions, represent a substantial proportion of yield (Anslow, 1967). Hunt and Brougham, 1966 and Rhodes, 1971 found it is essential that the stems be erect enough to be collected by harvesting since no benefit derived from increased stubble height (Anslow, 1971, Davies and Troughton, 1972 and Kneivel, Jacques, and Smith, 1971). Watson and Norman, 1939 and Thorne, 1957 recognized the photosynthetic contribution of leaf sheaths. Langer, 1958 attributed high relative growth rates after ear emergence to the additional photosynthetic area of leaf sheaths and ears.

Langer, 1959 found rate of dry matter production was increased by increasing residual foliage after cutting, but Simon, Davies, and Troughton, 1972 did not increase herbage production from perennial ryegrass by raising the height of cutting. By increasing the product of leaf area x time between harvests Sheard and Winch, 1966 increased the productivity of timothy, smooth brome, and cocksfoot. Davies, 1972 decreased the leaf number of ryegrass by increasing the height of cutting because leaf laminae were removed but stem apices left intact. Simon, Davies and Troughton, 1972 found no influence of height of cutting on

rate of leaf appearance in Lolium perenne.

In swards of Lolium perenne decreasing frequency of defoliation was associated with heavier tillers, more reproductive tillers, and higher total tiller number after the midsummer depression in tiller number (Anslow, 1967). Cutting either meadow fescue or timothy every four weeks did not alter the seasonal trend in tiller number (Langer, 1959). Knight, 1970 found number of sterile and fertile tillers of Dactylis glomerata reduced by frequent cutting but unaffected by harvesting at 4 to 6 week intervals. Uncut plants produced fewer reproductive tillers than plants which were defoliated.

Teel, 1956, Paulsen and Smith, 1969 and Reynolds and Smith, 1962 showed that productivity decreased with defoliation between the initiation of internode elongation to ear emergence because during this period shoot apices were susceptible to removal, carbohydrate reserves were minimal, and axillary buds were not developed. Kneivel, Jacques, and Smith, 1971 achieved maximum yields of smooth brome and timothy by cutting at early anthesis. Langer, 1959 found that cutting timothy before apices differentiated temporarily increased tiller number while cutting afterwards had the opposite effect.

Branson, 1953 found the proportion of vegetative to reproductive tillers in a sward influenced its regrowth, the more vegetative swards surviving best. For two weeks after

defoliation of orchard grass increased ground cover was due almost entirely to leaf expansion of nonflowering tillers (Taylor and Templeton, 1966). Jewiss, 1972 said that amounts of regrowth depend on both number and size of vegetative tillers present at the base of reproductive tillers at the time of cutting. Anslow, 1967 found that a few, large tillers of Lolium perenne gave the same regrowth as many small tillers. Taylor and Templeton, 1966 reported that stubble of fertile tillers of orchard grass was higher in stored carbohydrates than vegetative tillers.

2. Statistical and Genetic Analysis

The method of stepwise multiple regression described by Draper and Smith, 1967 was applied to bromegrass by Walton in 1976. He used yield of each of two harvests as dependent variables, and also used multiple regression to determine the independent variables associated with some tiller characteristics. Walton associated increased yield of forage with increased winter survival and plant height. Stepwise multiple regression also showed relationships between leaf number and stem weight and yield. The regression procedure established dependencies between tiller number and stem weight, stem weight and standard leaf weight and between standard leaf weight and leaf number per stem. Also leaf weight was related to stem area and stem area and leaf number were related by regression. Much of the variation in tiller number and size was explained.

Diallel crosses have been used by various workers to test the progeny of forage grass crosses (Dunn and Wright, 1970, Ross, Bullis, and Lin, 1970, Robinson and Thomas, 1963, Timothy, Thomas, and Kernkamp, 1959, Mishra and Drolsom, 1972, and Drolsom and Nielson, 1970). The method of diallel analysis described in 1956 by Griffing gives an estimate of general combining ability, specific combining ability, and reciprocal effects. Sprague and Tatum, 1942 defined general combining ability (GCA) as the average performance of a line in hybrid combination, while specific combining ability (SCA) was the difference between the performance of a cross and the average performances of the lines in the cross.

The GCA variance is one quarter of the variance due to additive gene action, while the SCA variance is one quarter of the variance due to dominance, epistasis, and genotype by environment interaction (Gardner, 1963). Hanson and Carnahan, 1956 reviewed the use of combining abilities for evaluating forage grasses. Robinson and Thomas, 1963, Dunn and Wright, 1970, Mishra and Drolsom, 1972, Walton, 1974, Tan and Dunn, 1976, Walton, 1976, and Tan, Tan, and Walton, 1976 found GCA larger than SCA for most morphological characteristics. Specific combining ability has been reported to be significant (Sleper and Drolsom, 1974, Walton, 1974, Tan and Dunn, 1976, and Drolsom and Nielsen, 1970). Knowles, 1950, Mishra and Drolsom, 1972, and Tan, Tan, and Walton, 1976 reported SCA larger than GCA for some

morphological characteristics. Sprague and Tatum, 1942 concluded that the relative importance of GCA and SCA depended upon the parental clones used. If the parents of a diallel have not undergone selection for their combining ability the variance for GCA was more important that the variance for SCA. If the parents have been selected for their combining ability the variance for SCA was more important than the variance for GCA. Where GCA is more important parents would be suitable for a multi-clone synthetic, whereas clones showing high SCA effects could be used as parents for two-clone synthetics. Reciprocal effects were significant for some traits of bromegrass (Knowles, 1950, Drolsom and Nielsen, 1970, Mishra and Drolsom, 1972, and Walton, 1974). Mishra and Drolsom, 1972 suggested that reciprocal effects are of little consequence in synthetic combinations when a number of clones is involved.

Troughton, 1971 described individual tiller weight and number as inherited to some degree independently, but Thompson, Wright and Rogers, 1973 and Cooper and Edwards, 1960 reported a negative correlation between tiller number and individual tiller weight. They also found differences between progeny in number and average and total dry weight of sterile and fertile tillers to be due to both general and specific combining ability.

Gardner, 1963 and Wright, 1970 derived procedures for estimating broad and narrow sense heritabilities. Broad

sense heritability (H_b) is that portion of phenotypic variation which is heritable, while narrow sense heritability (H_n) is that portion of the heritable variation which is due to additive gene action. Silsbury, 1966 described tiller weight and number as very sensitive to the environment. Troughton, 1971 said that the general level of energy substrates controls tiller number and size. Silsbury, 1966 was not encouraging about breeding for tiller number and weight as components of yield saying that tiller number has limited predictive value in determining dry weight since there is considerable variation between plants in tiller weight.

Hunt and Brougham, 1966 found significant differences among species on the amount of tissue present before a balance was achieved between leaf production and death. Simon, Davies, and Troughton, 1972 and Cooper and Edwards, 1960 found marked differences between genotypes in leaf weight and overall size. Cooper and Edwards, 1960 also found that selection for a rapid rate of leaf appearance in ryegrass resulted in smaller leaves and vise versa.

III. MATERIALS AND METHODS

The eight clones of *Bromus inermis* Leyss. (UA5, UA6, UA9, UA12, UA10, B40, B42, and 43) used in this experiment were selected from diverse sources. There were selections from commercial cultivars of northern, southern, and intermediate climatic adaptation. Some selections showed field resistance to *Pyrenophora bromi* (Dred.) and *Selenophoma bromigena* (Sacc.) when grown at Saskatoon, and a synthetic clone was susceptible to these diseases. One clone was selected from a long established pasture in Alberta. These clones gave a range of morphological type which is described in Table 1. These eight parents were crossed in all possible combinations using the mutual pollination method (Drolsom and Nielsen, 1970) and the complete diallel was established in the field at Edmonton in 1973. Four individual plants of each genotype of the eight parents, the F_1, and the reciprocal crosses were planted in a plot 60 cm. x 240 cm. The plots were arranged in a randomized block design. After two years of growth the four individual plants had grown together to form a sward completely covering the plot area. Each whole plot was harvested twice annually using a modified Mott mower.

At four dates in 1975 each plot in three replications was sampled by clipping all plant material from an area 8cm. x 20cm. at four locations in the sward. The sampling dates were May 22, June 9, June 25, and July 29, which correspond

with the initiation of growth, stem elongation, time of the first harvest, and three weeks of regrowth. The samples were frozen for storage and subsequently the tillers were counted and classified according to the types nonelongated, elongated, and headed tillers. A 10 tiller subsample was retained from each tiller type. Early in the season, when nonelongated tillers dominated the sward, the ten tiller subsample was a smaller proportion of the total tiller population than later in the season. When tillers began to elongate ten tillers often included the entire population of tillers within a category. The tiller characteristics observed on these subsamples were area and weight per tiller of leaves, stems, and heads, leaf number per tiller, stem length, individual tiller weight, leaf to stem ratio, average area per leaf, and standard leaf weight. Areas were determined using a Hayashi-Denko, Model AAM-5 automatic area meter. Leaf sheaths were included on the stem. Weights were determined after the plant parts were dried at 100 °F for 48 hours. Standard leaf weight was the weight per unit area of leaf. Average leaf area was the average size of leaf for each tiller type. The sward characteristics observed were vigor, spread, and height to the flag leaf at the time of each harvest. Vigor and spread were rated early in the season by a visual score, a rating of 4 was used for the most vigorous plants, while 3 indicated maximum spread of the bromegrass in the plot. The observations were expressed as plot means.

The association in the complete diallel of these tiller and sward characteristics with yield was analysed using simple correlation and stepwise multiple regression. First and second harvest yields were dependent variables in the regression formulae. Tiller characteristics were used as independent variables to determine which characteristics of tiller type and tiller morphology accounted, at each of the four sampling dates, for most of the variation in yield. Then sward characteristics were permitted to enter the regression analysis to derive equations predictive of yield. For parents, F_1, and the reciprocal crosses the association between tiller characteristics was analysed using simple correlation and stepwise multiple regression. Individual tiller weight and tiller number of each tiller type were dependent variables in regression analysis using all other tiller characteristics as independent variables. The stepwise multiple regression procedure used introduced independent variables into the regression equation according to the proportion of variation of the dependent variable for which they accounted. The regression analysis was considered complete when the introduction of a new independent variable resulted in a change of less than 1% of the variance of the dependent variable.

Griffing´s, 1956 method of diallel analysis was used to partition the mean squares of characteristics of single crosses which showed significant variation between genotypes according to an analysis of variance. The model used for

partitioning the general combining ability (GCA), specific combining ability (SCA), and reciprocal effects (RE) was:

$$Y_{ijk}=u+g_i+g_j+s_{ij}+r_{ij}+e_{ijk}$$

were u is the population mean effect, g_i (or g_j) is the GCA effect for the i^{th} (or j^{th}) parents, s_{ij} is the SCA effect for the cross between the i^{th} and j^{th} parents such that $s_{ij}=s_{ji}$, r_{ij} is the reciprocal effect and e_{ijk} is the residual error associated with the ijk^{th} plot. Since the plants were not selected for any of the characteristics under study Model 2 was used and Method 2, including parents, F_1, and reciprocals was appropriate. Model 1 is used when parents have been selected for the characters under study. The data was also analysed using Model 1, Method 2 to generate estimates of general and specific combining ability effects, since this information was needed to select parents suitable for a breeding program. Following procedures developed by Gardner, 1963 and Wright, 1970 broad sense heritability(H_b) and narrow sense heritability(H_n) were estimated as:

$$H_b=(4\hat{\sigma}^2_g+4\hat{\sigma}^2_s)/(4\hat{\sigma}^2_g+4\hat{\sigma}^2_s+\hat{\sigma}^2_r+\hat{\sigma}^2_e)$$

$$H_n=4\hat{\sigma}^2_g/(4\hat{\sigma}^2_g+4\hat{\sigma}^2_s+\hat{\sigma}^2_r+\hat{\sigma}^2_e)$$

where $\hat{\sigma}^2_g$, $\hat{\sigma}^2_s$, $\hat{\sigma}^2_r$ and $\hat{\sigma}^2_e$ are the GCA, SCA, reciprocal, and error variance components, respectively. Zero was used as an approximation of negative variances after the manner of Mishra and Drolsom, 1972.

IV. RESULTS

1. General Trends in Tiller Characteristics

As shown in Figure 1 the total number of bromegrass tillers increased from the first sampling date (34 tillers) to the second sampling date and was slightly higher in the regrowth sward (94 tillers). Changes in total tiller number between the second and third sampling dates were associated with genotype (Table 2). The number and size of nonelongated tillers fell from the first to the third sampling date, then rose after the first harvest. The number and size of headed tillers rose from the second to the third sampling date, then fell after the first harvest. The number of elongated tillers fell until the third sampling date, rising then until the fourth (Table 2). Elongated tillers of genotypes B40, B42, UA5, and UA10 were smaller at the third than the second sampling date. As the tillers recovered from defoliation elongated tillers of B40, B42, and UA10 increased in almost all characteristics, while UA5 only increased in stem size. Between the second and third sampling dates the elongated tillers of UA6 and 43 increased in leaf size and became less stemmy. After the first harvest elongated tillers of clone 43 increased in leaf and stem size, while UA6 only increased in stem size. UA9 elongated tillers decreased in weight and leafiness between the second and third sampling dates and produced stemmy regrowth. Leaves and stems of UA12 grew before the first harvest but mainly stems grew afterwards. Elongated tillers of B40, B42,

and UA10 grew least vigorously before defoliation, and recovered most vigorously. UA5, UA6, UA9, and UA12 yielded stemmy regrowth. There is thus genotypic variation in the reaction of elongated tillers to defoliation (Table 2).

2. The Association Between Tiller Characters Within Tiller Types

Generally, throughout the season, increasing individual tiller weight within a tiller type was positively correlated with increasing number, area, and weight of leaves per tiller, stem length and area per tiller, and head area and weight of the tillers (Tables 3 and 4). Also the number, area, and weight of leaves, length, area, and weight of stems, and weight and area of heads were all positively correlated within tiller types (Tables 3 and 4). Multiple regression equations related individual tiller weight of each tiller type positively to the leaf area per tiller and standard leaf weight of tillers within that tiller type throughout the season (Tables 5,6, and 7). At the first sampling date individual nonelongated tiller weight was negatively associated with number of nonelongated tillers (Tables 3, 5, and 8). The leaf to stem ratio of elongated tillers was negatively related by multiple regression to individual tiller weight throughout the season (Table 6).

The multiple regression equations showed that number of nonelongated tillers was positively related to number of

leaves per tiller within the category throughout the season (Table 8). Stem length of elongated and headed tillers were positively related by correlation and regression to number of tillers within their respective categories (Tables 3,4,9, and 10). Leaf to stem ratio of elongated tillers was negatively correlated with tiller number at the second sampling date (Table 3). Regression analysis also related elongated tiller number and standard leaf weight negatively at the second sampling date (Table 9). Leaf to stem ratio of elongated tillers was negatively correlated with their tiller number at the fourth sampling date (Table 4), while multiple regression related leaf weight per elongated tiller negatively to their tiller number at this time (Table 9). Multiple regression related number of headed tillers negatively to the leaf weight per headed tiller and standard leaf weight of headed tillers at the second and third sampling dates respectively (Table 10). The standard leaf weight of headed tillers was negatively correlated with their tiller number at the third sampling date (Table 4).

3. The Association Between Tiller Types

Throughout the season, for nonelongated and elongated tillers, an increase in the weight of individual tillers of one type was associated with a decrease in the number of tillers of the other type (Tables 3,4,5, and 8). At the second sampling date the weight of leaves per elongated tiller was negatively related to number of nonelongated

tillers (Tables 3 and 8). At the third sampling date the size of leaves of nonelongated tillers was negatively related to number of elongated tillers (Table 9). By the time of the third sampling date stems had developed so that their increasing size was negatively correlated with size of nonelongated tillers (Table 4). At the fourth sampling date number and weight of nonelongated tillers were negatively related to leaf and stem size of elongated tillers (Tables 4 and 8).

At the second and fourth sampling dates the nonelongated tillers resembled the elongated tillers in that both types of tillers increased in weight and number as the two types of tillers followed a similar growth pattern (Tables 3,8, and 9).

Nonelongated and headed tillers were associated negatively throughout the season (Tables 3,4,5, and 8). At the second sampling date increasing number of either nonelongated or headed tillers was associated with decreasing size of tillers of the other type (Tables 3 and 8). At the fourth sampling date the tiller numbers of the two types of tillers were negatively correlated and number of nonelongated tillers was negatively correlated with individual headed tiller weight (Table 4).

Elongated and headed tillers were negatively related at the second and third sampling dates since increasing number of tillers of one type was associated with decreasing

individual tiller weight of tillers of the other type (Tables 3,4,6, and 9). At the second sampling date the number of headed tillers was negatively related to leaf and stem characteristics of elongated tillers (Tables 3 and 10). At the third sampling date elongated tiller number was negatively related to nearly all characteristics of headed tillers, but there were positive correlations between size of elongated and headed tillers (Table 4). At the fourth sampling date also there were positive correlations between elongated and headed tiller characteristics (Table 4).

4. Tiller Characters Associated with the Yield of the First Harvest

At the first sampling date regression and correlation related the number of nonelongated tillers positively to first harvest yield (Tables 11,13, and 14). Regression also related the leaf area per nonelongated tiller positively to yield (Tables 13 and 14). At the second sampling date first harvest yield was positively correlated with the weight and number of headed tillers and the number, area, and weight of leaves per headed tiller (Table 11). Regression analysis related yield positively to the length of headed tiller stems (Tables 13 and 14). At the second sampling date first harvest yield was negatively correlated with number and weight of nonelongated tillers, their leaf number and weight per tiller, and their standard leaf weight (Table 11). Regression analysis also related number of leaves per

nonelongated tiller negatively to yield (Tables 13 and 14). Regression and correlation associated the standard leaf weight of elongated tillers negatively with first harvest yield (Tables 11, 13, and 14) and the correlation of leaf to stem ratio of elongated tillers with yield was negative (Table 11).

At the third sampling date negative correlations with the first harvest yield predominated. The number of nonelongated tillers, their weight, average area per leaf, and their leaf number, weight, and area per tiller were all negatively correlated with yield (Table 11). Regression analysis related first harvest yield negatively to individual nonelongated tiller weight, weight of headed tiller stems, and the leaf weight per headed tiller (Tables 13 and 14). Positive correlations were found between first harvest yield and the stem lengths of elongated and headed tillers and the number of headed tillers (Table 11). Regression related the length of headed tiller stems positively to first harvest yield (Table 14).

By the time of the fourth sampling date none of the tiller characteristics were correlated with yield of the first harvest. Regression related number of nonelongated and elongated tillers positively, and individual nonelongated tiller weight and number of headed tillers negatively to first harvest yield (Tables 13 and 14).

5. Tiller Characters Associated with the Yield of the Second Harvest

At the first sampling date correlation and regression related number of nonelongated tillers positively to second harvest yield (Tables 11, 15, and 16), and regression showed a positive relationship between leaf area per nonelongated tiller and yield (Table 16).

At the second sampling date the number of elongated tillers was positively related to second harvest yield by regression (Table 15), and regression and correlation showed a positive association between yield and area of elongated tiller stems (Tables 11 and 16). There was a positive correlation between yield and elongated tiller stem length (Table 11). Correlation and regression related number of headed tillers and their stem length positively to yield of the second harvest (Tables 11, 15, and 16). Stem area per headed tiller was also positively correlated with yield (Table 11). At the second sampling date the standard leaf weight of both nonelongated and elongated tillers was negatively correlated with second harvest yield (Table 11). Regression related individual elongated tiller weight and stem weight per headed tiller negatively to yield (Table 16).

At the third sampling date regression analysis related number of elongated tillers positively to second harvest yield (Table 15). Regression and correlation showed positive

associations between number of headed tillers and their stem length and second harvest yield (Tables 11, 15, and 16). Stem area per headed tiller was also positively correlated with yield (Table 11). Regression and correlation showed a negative association between yield and the standard leaf weight of headed tillers (Tables 11 and 16).

At the fourth sampling date regression related nonelongated tiller number positively to second harvest yield (Table 15). The number of elongated and headed tillers, their weight, their leaf number and leaf area, the average area of their leaves, their stem lengths, areas, and weights were all positively correlated with the yield of the second harvest (Table 11). Regression analysis also showed positive associations between length of elongated tiller stems and number of headed tillers and yield (Tables 15 and 16). There was a negative correlation between yield and standard leaf weight of nonelongated tillers at the fourth sampling date (Table 11). Correlation and regression showed a negative relationship between elongated tiller standard leaf weight and yield (Tables 11 and 16). Regression analysis also related elongated tiller leaf to stem ratio negatively to second harvest yield (Tables 15 and 16).

6. Tiller Characters Associated with Total Yield

At the first sampling date number of leaves per tiller and number of nonelongated tillers were positively

correlated with yield totalled over both harvests (Table 11). When the second sample was taken total yield was positively correlated with number and weight of headed tillers and their number and area of leaves per tiller. The size and number of nonelongated tillers was negatively correlated with total yield. At the third sampling date tiller number and stem length of headed, and stem length of elongated tillers were positively correlated with total yield. Number and weight of nonelongated tillers, their number, area and weight of leaves per tiller, and average area per leaf as well as standard leaf weight and leaf to stem ratio of headed tillers were negatively correlated with total yield. At the fourth sampling date number, leaf and stem area, and stem length of elongated tillers were positively correlated with total yield. Leaf to stem ratio and standard leaf weight of elongated tillers were negatively correlated with total yield.

7. Sward Characters Associated with Yield

For the sward characteristics the correlations between combined and individual yields, vigor, and heights of both harvests were all significant (Table 12). For all sampling dates vigor accounted for most of the variation in first harvest yield (Table 13). Height at the first harvest was included in the regression equation on first harvest yield at the first, third, and fourth sampling dates (Table 13). Spread was included in the regression equation on first

harvest yield at the first sampling date. Throughout the season height at the second harvest accounted for most of the variation in second harvest yield (Table 15). The regression analysis indicated that vigor was an important component of second harvest yield at the first and third sampling dates (Table 15).

8. The Genetics of Tiller and Sward Characteristics

The analysis of variance showed significant differences between genotypes for all characteristics reported in Table 2, except first harvest yield. General combining ability was significant for nearly every trait studied (Table 17). Fewer specific combining abilities were significant. In most cases the mean square values for general combining ability were substantially larger than the values for specific combining ability. Reciprocal effects were significant for a few of the traits studied. The general combining ability effects of UA12 were consistently low for all traits, though only the total yield GCA effect of B42 was low (Table 17). The GCA effects for UA10 were high for total yield, second harvest yield, height at the second harvest, and vigor. SCA effects for selected characters are listed in Table 19.

The broad and narrow sense heritabilities are presented in Table 17. Of the tiller and sward characteristics related to yield broad sense heritabilities were high for height at the second harvest, leaf area per nonelongated tiller at the

first sampling date, individual elongated tiller weight at the second sampling date, and, at the third sampling date, individual nonelongated tiller weight, and leaf and stem weight of headed tillers. At the fourth sampling date broad sense heritability was high for the number of nonelongated tillers. Intermediate magnitudes of broad sense heritability were recorded for height at the first harvest, vigor, number of nonelongated tillers early in the season, area of elongated tiller stems at the second sampling date, and length and weight of headed tiller stems at this time. At the third sampling date broad sense heritability of headed tiller number and stem length was intermediate, and at the fourth sampling date broad sense heritabilities of elongated tiller number and stem length were intermediate. Broad sense heritabilities of elongated tiller standard leaf weight were low at the second and fourth sampling dates, that of headed tillers was low at the third sampling date, and number of headed tillers at the fourth sampling date had a low broad sense heritability. Narrow sense heritabilities were low for nearly every characteristic associated with yield except height at the second harvest, individual elongated tiller weight at the second sampling date, weight of leaves per headed tiller and their stem weight at the third sampling date, and nonelongated tiller number at the fourth sampling date. Also at the fourth sampling date narrow sense heritabilities were not low for average area per leaf, area and weight of leaves per tiller, stem length and area, and

individual tiller weight of elongated tillers.

V. DISCUSSION

Walton, 1976 found that increased standard leaf weight of bromegrass was negatively related to yield though it should be associated with greater photosynthetic efficiency. In the present study morphologic characters changed their relationship to dry matter accumulation at three levels of complexity. The relationship of tiller characters to yield should be discussed as their interaction in parts of tillers, whole tillers, and the complete sward.

1. The Accumulation of Photosynthates in Parts of Tillers

Both total area and photosynthetic efficiency of leaves, leaf sheaths, stems, and heads affect the contribution of tiller parts to the accumulation of photosynthates in a bromegrass sward. Increased leaf area per tiller is associated with increased individual tiller weight within the tiller type throughout the season (Tables 5,6, and 7). At the first and third sampling dates increased leaf area per nonelongated tiller was associated with decreased nonelongated tiller number (Tables 3 and 8) yet at the third sampling date increasing average area per nonelongated tiller leaf was associated with an increase in the number of nonelongated tillers (Table 8). Tillers have limited supplies of photosynthate with which they can either expand their leaf area per tiller or increase their tiller number, however greater photosynthetic ability can improve

tiller survival. At the fourth sampling date leaf area per elongated tiller was positively related to the number of these tillers (Table 9), but leaf area per headed tiller was negatively related to their tiller number (Table 10). Possibly the leaf area of headed tillers had expanded to the extent that further increases only added to shading and consequent loss of dry matter. Generally increased stem area of elongated and headed tillers was positively associated with increased individual tiller weight and tiller number within the tiller type (Tables 3,4,6, and 7). At both the third and fourth sampling dates head area per headed tiller was positively related to the weight of individual headed tillers (Table 7) and at the fourth sampling date head area was positively associated with the number of headed tillers (Table 4).

Increasing standard leaf weight has been associated with increasing photosynthetic efficiency (Pearce et al., 1969). In this study increasing standard leaf weight of a tiller type was positively associated with increasing individual tiller weight of that tiller type throughout the season, (Tables 3,4,5,6, and 7) but the relationship of standard leaf weight to dry matter accumulation depended upon what use the tiller made of the photosynthates. At the first and third sampling dates number of nonelongated tillers was positively related to their standard leaf weight (Tables 4 and 8). Standard leaf weight and leaf to stem ratio of elongated tillers were negatively related to

elongated tiller number at the second sampling date (Tables 3 and 9) and leaf to stem ratio and leaf weight of elongated tillers were negatively related to elongated tiller number at the fourth sampling date (Tables 4 and 9). This suggests that while accumulation of photosynthates may be increased, the use of photosynthates for increasing the weight of leaves over and above the weight of stems can aggravate competetion and decrease tiller number through senescence.

The relationship of standard leaf weight to yield reflects the plant's dependence upon the use of photosynthates. At the second sampling date the standard leaf weight of elongated tillers was negatively related to first and second harvest yield, while at the fourth sampling date it was negatively related to yield of the regrowth harvest (Tables 11,13,14, and 16). A similar but less pronounced relationship exists between standard leaf weight of headed tillers, their tiller number, and the accumulation of dry matter. At the second sampling date number of headed tillers and their leaf weight per tiller were negatively related, indicating that an increase in leaf weight could be deterimental to the initiation of headed tillers (Table 10). At the third sampling date number and standard leaf weight of headed tillers were negatively related (Tables 4 and 10). Possibly the increased standard leaf weight contributes to senescence of some headed tillers due to increased competetion between leaves. At the third sampling date leaf weight of headed tillers was negatively related with first

harvest yield (Table 13) and standard leaf weight of headed tillers was negatively related to yield of the regrowth harvest (Tables 11 and 16).

It has been suggested that the accumulation of dry matter in a grass sward would be maximized when photosynthates are invested in expanding larger photosynthetic areas (Ryle, 1968). This would occur when leaf to stem ratio increased. It is seen however that increasing leaf weight and leaf to stem ratio of elongated tillers at the second sampling date, and leaf to stem ratio at the fourth sampling date, were negatively related to yield (Tables 11 and 16). At the third sampling date the leaf weight per headed tiller was negatively related to the first harvest yield (Table 13), while leaf to stem ratio of headed tillers was negatively related to yield of the regrowth harvest (Table 11). Thus as the weight of leaves increases there is greater competetion between leaves and hence increased senescence. Other authors have stressed the need to control leaf development at certain times of the growing season to encourage tillering (Brown and Blaser, 1968). It seems that after a certain leaf to stem ratio is established, further attempts to increase weight of leaves results in only a transitory accumulation of photosynthate.

2. The Accumulation of Photosynthates in Whole Tillers

The three different types of tillers in the sward

contribute in different ways to the accumulation of yield throughout the season. At the first sampling date the number of nonelongated tillers and their leaf area per tiller was positively related to yield of the first and second harvests (Tables 11,13,14,15 and 16). Ryle, 1964 found the expansion of a large photosynthetic area as early as possible in the season important to yield. Later on in the season however nonelongated tillers became a detriment to yield since they were not tall enough to be cut at harvesting. Number and individual tiller weight of nonelongated tillers and their number of leaves per tiller were negatively related at the second and third sampling dates to first harvest yield (Tables 11, 13, and 14). The nonelongated tillers did, however, contribute to yield of the regrowth harvest from the time of the fourth sampling when increased number of nonelongated tillers probably contributes to better recovery from defoliation (Table 15). There was also a positive relationship between number of nonelongated tillers at the fourth sampling date and first harvest yield (Table 13). It is possible that the population of tillers present in the regrowth sward closely resembles the tiller population with which the bromegrass would initiate growth the next season. If this were the case then a high density of nonelongated tillers might give the sward superior early season growth. Elongated tillers could also contribute to the perennial habit of the bromegrass. Swards with a high density of headed tillers after the first harvest would have fewer

tillers surviving until the next season but might have a higher seed yield. This would explain the positive relationship between elongated tiller number at the fourth sampling date and first harvest yield, and the negative relationship at this time between headed tiller number and yield of the first harvest (Tables 13 and 14).

The elongated tillers contribute more to the second harvest yield than the first. At the fourth sampling date the number of elongated tillers and their individual tiller weight was positively related to yield of the regrowth harvest (Table 11). This is probably the direct effect of more and larger tillers contributing to yield. Number of elongated tillers at the second and third sampling dates was positively related to second harvest yield (Table 15) but individual elongated tiller weight at the second sampling date was negatively related to yield of the regrowth harvest (Table 16). Taylor and Templeton, 1966 have emphasized the importance to recovery from defoliation of vegetative tillers which provide a rapidly expanding photosynthetic area after the first harvest. This study also suggests that elongated tillers supply carbohydrate reserves to the defoliated sward. If the elongated tillers use too much of their photosynthetic assimilates for growth before the first harvest, carbohydrate storage is reduced and the second harvest yield suffers. This is consistent with the observation from the general trends in tiller characteristics that elongated tillers of some genotypes

grow best before, and others after the first harvest.

Headed tillers were positively related at the second sampling date to the first harvest yield, and at the fourth sampling date to the second harvest yield, through individual tiller weight and number (Tables 11,15, and 16). Investigators have associated maximum crop growth rate with inflorescence emergence, (Langer, 1959 and Anslow, 1965) which explains why headed tillers make the dominant contribution to yield. Weight of headed tiller stems at the third sampling date was negatively related to first harvest yield (Table 14). Possibly when tiller stems were heavy tiller number was reduced. Number of headed tillers at the second and third sampling dates was positively related to yield of the regrowth harvest (Tables 11,15 and 16). Reproductive tillers have been shown to store more nonstructrual carbohydrate for regrowth than vegetative tillers, (Taylor and Templeton, 1966) so possibly greater densities of headed tillers prior to the first harvest improve carbohydrate reserves. The weight of headed tiller stems at the second sampling date was negatively related to regrowth harvest yield (Table 16). A large increase in weight of stems early in the season may mean that less carbohydrate is stored in the roots for regrowth.

Increasing stem length of both elongated and headed tillers contributes throughout the season to the accumulation of dry matter (Table 11). First and second

harvest yields were positively related to length of headed tiller stems at the second and third sampling dates (Tables 13,14, and 16). Length of elongated tiller stems at the fourth sampling date was positively related to second harvest yield (Table 16). Increasing stem length maintains dry matter in a harvestable condition because it raises the plant material above the height of cutting. Anslow, 1967 stressed the importance of erectness in relation to productivity of a sward. Also the greater stem length improves leaf distribution so light penetrates deeper into the sward, minimizing leaf loss through senescence.

3. The Accumulation of Photosynthates in the Sward

The ability of nonelongated tillers to establish a large photosynthetic area early in the season makes them important to yield. Elongated tillers can grow in the regrowth sward and contribute to second harvest yield. The high crop growth rate characteristic of headed tillers makes a direct contribution to yield of both harvests. The stems of both elongated and headed tillers are important to yield. At the whole tiller level these specific tiller characteristics control the contribution which tillers make, through individual tiller weight and number, to yield.

Since different types of tiller contribute at different times of the year to the accumulation of yield, the ideal grass sward should enhance the production at different times

of those specific tiller types which contribute most to yield. At the sward level of production the competetion between the three types of tillers is an important determinant of the weight and number of tillers. For nonelongated and elongated tillers an increase in the weight of individual tillers of one type was associated with a decrease in the number of tillers of the other type throughout the season (Tables 3,4,5, and 9). At the second sampling date this relationship was expressed through the weight of leaves per elongated tiller which was negatively related to number of nonelongated tillers (Tables 3 and 8) The bromegrass utilizes photosynthates in increasing weight of elongated tiller leaves rather than increasing the number of nonelongated tillers. It has been reported that photosynthate is transported from mature leaves first for the expansion of other leaves, and secondarily for the development of axil buds (Milthorpe and Ivins, 1966). This suggests competetion for carbohydrates which also occurs at the third sampling date when the size of leaves of nonelongated tillers was negatively related to number of elongated tillers (Table 9). By the time of the third sampling date stems had developed so their increasing size was negatively associated with the size of nonelongated tillers (Table 4). At the fourth sampling date number and weight of nonelongated tillers were negatively related to leaf and stem size of elongated tillers (Tables 4 and 8). Both these relationships are examples of competetion between

types of tillers for light, the larger type of tiller reducing the growth of the smaller tiller.

At the second and fourth sampling dates the nonelongated tillers resembled the elongated tillers in that both types of tillers increased in weight and number as the two types of tillers followed a similar growth pattern (Tables 3,8, and 9). There are many other statistically significant but low positive correlations between tiller characteristics of nonelongated and elongated tillers. Mishra and Drolsom, 1972 found that size of tiller parts was correlated with whole tiller size in a similar manner. They concluded that the correlations reflected a relationship to general size. In this study the positive relationship found between tiller characteristics of different types of tillers is probably the result of general increases in size occurring in tillers of all types. This is also shown at the third and fourth sampling dates when there were positive associations between elongated and headed tiller Fharacteristics (Tables 4,6, and 10).

Nonelongated and headed tillers were associated competetively throughout the season, with the larger headed tillers shading the nonelongated tillers. Williams, 1970 reported reduced nonelongated tiller number in swards with fertile tillers due to shade suppression of apical buds. In this study, at the second sampling date, increasing numbers of either nonelongated or headed tillers was associated with

decreasing size of tillers of the other type (Tables 3 and 8). At the fourth sampling date the tiller numbers of the two types of tillers were negatively associated and number of nonelongated tillers was negatively related to individual headed tiller weight (Table 4).

Elongated and headed tillers were negatively related at the second and third sampling dates since increasing number of tillers of one type was associated with decreasing individual tiller weight of tillers of the other type (Tables 3,4,6, and 9). At the second sampling date the number of headed tillers was negatively related to leaf and stem characteristics of elongated tillers (Tables 3 and 10) probably because the bromegrass can either invest photosynthate in increasing the size of elongated tillers or use it to develop inflorescences. At the third sampling date elongated tiller number was negatively related to nearly all characteristics of headed tillers because the headed tillers were larger than the elongated tillers at this time, and so dominated in the competetion for light (Table 4).

Generally tiller characteristics which improved the competetive ability of a tiller were positively related to yield. For example, the stem length of elongated and headed tillers was positively related to number of tillers within their respective categories (Tables 3,4,9, and 10) and length of stems was positively related to yield (Tables 11,13,14, and 16). However, some competetive relationships

between types of tillers are detrimental to the accumulation of dry matter. At the fourth sampling date the number and individual tiller weight of headed tillers were positively related to yield of the second harvest (Tables 11, 15, and 16). However these characteristics of headed tillers were negatively related with the number of nonelongated tillers at the fourth sampling date (Table 4) and greater number of nonelongated tillers at this time was associated with greater yield of the first harvest. The tiller characteristics which contributed to first harvest yield detracted at the same time from the second harvest yield.

Sward characteristics accounted for much of the variation in yield of both harvests (Tables 13 and 15). Early season vigor even influenced yield of the second harvest (Table 15). This agrees with Walton's (1976) findings that differences in winter survival are very important even in bromegrass which is usually regarded as being winter hardy. Height at the time of the respective harvests was also strongly positively related to yield (Tables 13 and 15). The spread of individual plants in the sward was only predictive of first harvest yield early in the season (Table 13).

The results of this study suggest that a bromegrass cut at two harvests should have, for maximum yield of the first harvest, a vigorous sward early in the season with a dense population of nonelongated tillers having a high leaf area.

Thereafter the population of nonelongated tillers should diminish. Two to three weeks later elongated tillers should be developed with long stems and high stem area, but not with so great a weight of leaves that competetion becomes intense. Also at this time there should be a dense population of large headed tillers. At the time of the first harvest the elongated and headed tillers should have long stems but the stems and heads of fertile tillers should not be unduly heavy.

For maximum yield of the second harvest the bromegrass should have a dense population of nonelongated tillers with a high leaf area early in the season. Vigorous growth at this time is essential. Two weeks later a large number of headed tillers will make an important contribution to yield. Stems of elongated and headed tillers should be long and have a large photosynthetic area, but the stem weight of headed tillers should not be increased at the expense of stored photosynthate. Also the weight of elongated tillers should not be increased to the detriment of carbohydrate storage for regrowth. At the time of the first harvest there should be a dense population of headed tillers with long stems and a high stem area. Leaf weight of headed tillers should not be increased to the point that leaves become competetive. Three weeks after the first harvest the regrowth sward should have many and large elongated and headed tillers. The headed tillers should dominate the sward and leaf weight of elongated tillers should not increase so

much as to become competetive. A large number of vegetative tillers and a small number of fertile tillers in the regrowth sward would improve yield of the first harvest in the following season. The ideal bromegrass would produce a tall sward throughout the season.

This ideotype stresses that stems are important in the accumulation and maintenance of photosynthate because increasing length of stems improves canopy structure and erectness of the sward. The contribution of leaves is variable because leaf senescence is a problem. Stems however do not senesce as rapidly as leaves since there was little tiller death in the bromegrass sward. Anslow, 1967 tried to cut forage grasses frequently enough to catch leaves before they became senescent, but acheived no increase in yield. It must be accepted that stem development is essential for maximum bromegrass yield. Between inflorescence emergence and anthesis crop growth rates are maximal (Anslow, 1965). Also, after the flag leaf emerges leaf loss declines (Ryle, 1964, Hunt and Brougham, 1966). Early anthesis would be the optimal time for cutting a bromegrass, since the desired development of stems would take place without increasing the loss of leaves. Delaying the first harvest until late anthesis may reduce the vigor of regrowth though no such effect was observed in this experiment. There is evidence that the longer apical buds are suppressed by stem elongation, the slower they are to initiate growth (Milthorpe and Ivins, 1966) so the sward could be harvested

earlier or selections could be made for genotypes more resistant to defoliation.

The second harvest should also occur when stems are well elongated and inflorescence development is advanced. Since early season vigor is so important the sward should have sufficient residual leaf area after the second harvest to enter the winter with a good supply of photosynthate.

All of the characteristics described in the ideotype should be considered when evaluating a bromegrasses´ yielding potential, but it is necessary to limit criteria for inclusion in a specific selection index. These characteristics should be easy to measure and highly heritable. If only those characters with good narrow sense heritability are considered a selection index for first harvest yield would include, at the second sampling date, individual headed tiller weight and leaf weight per headed tiller. Also, at the fourth sampling date nonelongated tiller number could be included in the index with a positive coefficient. A plant breeder could select against high leaf and stem weight of headed tillers at the third sampling date.

If characters with good broad sense heritability are used in a selection index for first harvest yield the characters with positive coefficients would include height of the sward throughout the season, early season vigor, leaf area of nonelongated tillers at the first sampling date,

number of elongated tillers at the second sampling date, length of headed tiller stems at the third sampling date, and number of nonelongated tillers at the fourth sampling date. Characters which could be used to eliminate parents are individual elongated tiller weight at the second sampling date and individual nonelongated tiller weight and leaf weight per headed tiller at the third sampling date.

Of the characters influencing second harvest yield narrow sense heritability is high enough to select for height of the sward, stem area per headed tiller at the third sampling date, and nonelongated tiller number at the fourth sampling date. Selection should eliminate those bromegrass parents with high individual elongated tiller weight at the second sampling date.

A selection index employing characters with high broad sense heritability would include height of the sward, vigor, leaf area per nonelongated tiller at the first sampling date, number of elongated tillers at the second sampling date, stem length and area of headed tillers at the third sampling date, and nonelongated tiller number at the fourth sampling date. These characters were positively related to yield, but individual elongated tiller weight at the second sampling date could be included in the index with a negative coefficient.

In both the present study and Walton's study in 1976, tiller characters observed before the time of the first

harvest accounted for more of the variation in yield of the second rather than the first harvest yield (Tables 13, 14, 15, and 16). This implies that stored carbohydrates are important determinants of yield, and should be considered in yield predictions.

The southern type bromegrasses and disease resistant clones yielded least. Walton, 1974 suggested that inbreeding depression could have reduced the vigor of the disease resistant plants. He stressed the importance of maintaining heterozygosity in the bromegrass population. The southern type clones could have responded poorly to the Edmonton environment. The cross of the disease susceptible synthetic with the selection from Lincoln was slightly infected with foliar diseases early in the season.

The general combining ability effects of UA12 were consistently low for all characteristics, though only the total yield GCA effect of B42 was really low (Table 17). The GCA effects for UA10, the disease susceptible synthetic were high for total yield, second harvest yield, height at the second harvest, and vigor. Morphologically UA10 was uniform, growing with an erect, nonspreading habit and medium width dark green leaves. UA10 was the tallest clone, the first to reach heading, and it showed good early season vigor. It meets the requirements for yielding ability suggested by the crop ideotype. B40, a resistant clone, yielded least at the first harvest, while UA12, the random selection from

incoln, gave the lowest yield of second and total harvests. Plants of B40 had the lowest tiller density throughout the season, with a spreading, prostrate habit. Leaves were pale blue-green and large in area. Individual tiller weight of B40 nonelongated, elongated, and headed tillers was higher than that of any other clone throughout most of the season. UA12 showed variation in leaf morphology throughout the experiment, but the growth habit was always erect, nonspreading, with short stems and the highest tiller density after the first sampling date. It is interesting that the extremes of tiller weight and number gave the lowest yield. It was observed earlier that elongated tillers of B42 and UA10 grew least vigorously before defoliation, and recovered most vigorously, yet B42 and UA10 were widely different in contribution to total yield. This emphasizes the fact that other tiller types, besides elongated tillers, influence the accumulation of total yield, and that total yield is the result of two harvests both of which are controlled by different tiller characteristics. Walton, 1974, Tan, Tan, and Walton, 1976, and Walton, 1976, also found UA10 relatively high yielding and UA12 less productive. The contribution of B42 was variable. UA10 appears to be the most valuable parent although UA9 yields almost as well. Unless there is no threat from foliar disease it would be better to use the selection from Carlton than the susceptible clone as a parent. The selection from the long established pasture, 43, yielded well at the first

harvest but contributed less to the second harvest. It could be included in a synthetic designed for one harvest of hay. The selection from Magna would ensure a good seasonal distribution of yield. The results of this experiment suggest that selections from Carlton and Magna be combined in a synthetic cross, possibly with the addition of 43 and the disease susceptible synthetic.

Table 1. Bromegrass clones used as parents in an 8x8 diallel, 1973.

Clone	Description
UA9	Random selection from Carlton Northern type bromegrass nonspreading, fine stems, lodged
UA5	Random selection from Magna Intermediate northern - southern type bromegrass moderately spreading, some coarse stems broad, erect leaves
UA6	Random selection from Redpatch Southern type bromegrass spreading, tall stems many narrow leaves
UA12	Random selection from Lincoln Southern type bromegrass spreading, coarse stems broad leaves
B40	Selection showing resistance to Selenophoma bromigena and Pyrenophora bromi very coarse stems very broad pale blue-green leaves
B42	Selection showing resistance to Selenophoma bromigena and Pyrenophora bromi coarse stems broad pale blue-green leaves
UA10	Synthetic susceptible to foliar diseases nonspreading, tall stems early heading
43	Selection from old pasture in Alberta moderately spreading high tiller density

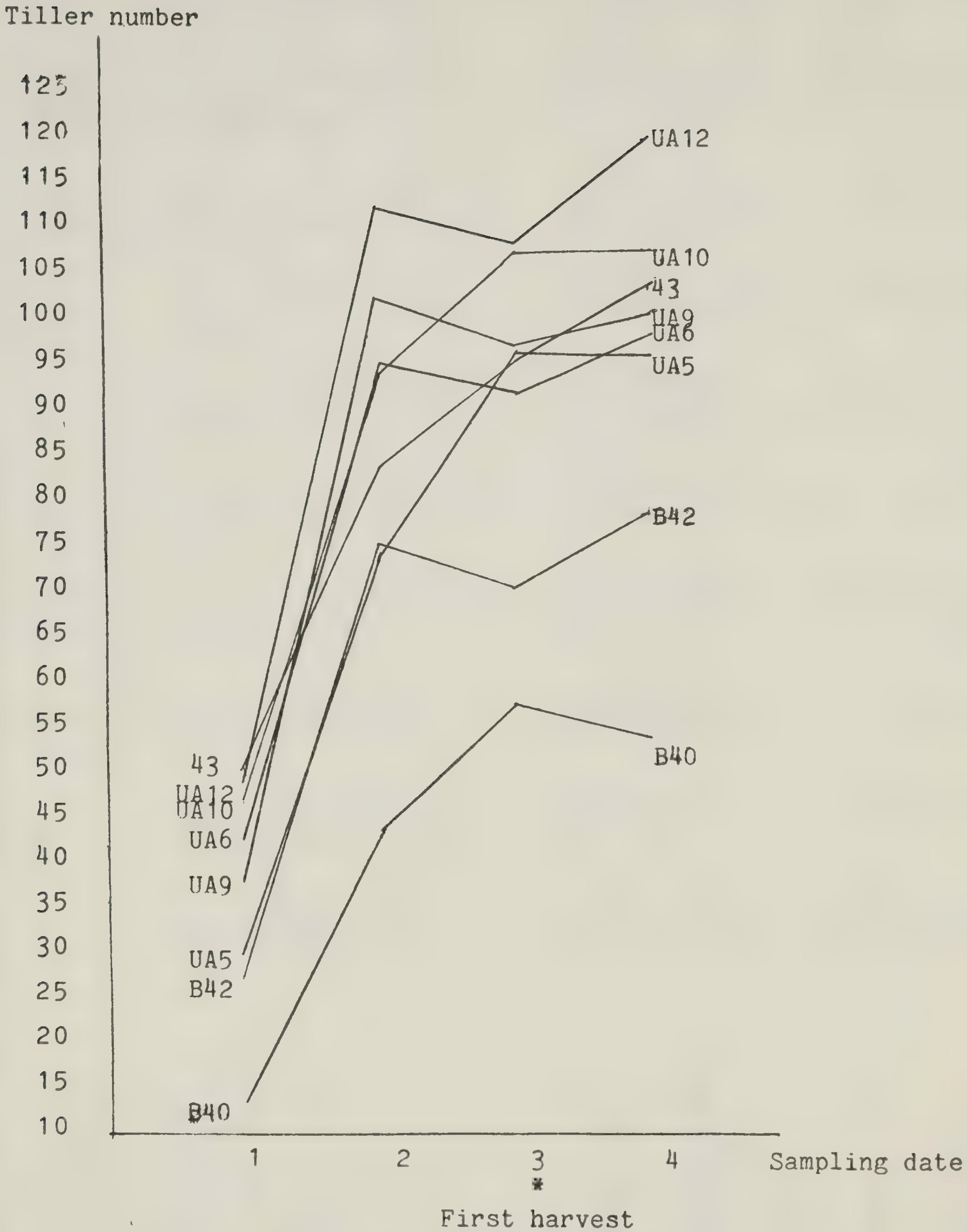

Figure 1. Seasonal trends in total tiller number

Table 2. Mean values of morphological characters and forage yield for eight parental bromegrass clones, 1975.

Parents	B40	B42	UA9	UA12	UA5	UA6	UA10	43	EXP. MEAN	STD. ERR.
SWARD CHARACTERS										
Total Yield (gm/plot)	222	261	265	216	267	276	288	255	259**	29.0
First Harvest Yield (gm/plot)	123	152	145	145	155	156	158	146	148	22.4
Second Harvest Yield (gm/plot)	98	109	120	71	112	119	129	108	110**	14.8
Mean Height (cm)	72.4	72.4	69.9	52.4	67.9	66.0	73.9	68.1	70.7**	4.36
First Height (cm)	89.6	88.3	84.5	67.8	88.0	79.5	89.5	86.5	86.9**	5.64
Second Height (cm)	55.1	56.6	55.3	37.0	47.8	52.6	58.3	49.6	54.4**	5.25
Spread	3.0	2.6	3.0	2.6	3.0	2.6	2.6	2.3	2.7**	0.42
Vigor	3.3	4.0	4.0	2.3	4.0	3.0	4.0	3.6	3.5**	0.43
TILLER CHARACTERS										
First Sampling Date										
Nonelongated Tillers:										
Tiller number	13.6	28.3	37.3	42.3	29.6	38.3	40.0	46.0	32.4**	8.75
Whole Tiller Weight (gm)	0.18	0.16	0.11	0.13	0.15	0.13	0.12	0.14	0.15**	0.028
Leaf Number	3.1	3.3	3.3	3.2	2.8	3.5	3.3	3.3	3.2**	0.26
Leaf Area (cm)	31.0	24.5	15.6	21.2	22.8	23.3	24.4	21.4	22.7**	0.40
Standard Leaf Weight (mg/cm)	6.2	6.3	7.4	6.3	7.3	6.2	5.1	7.2	6.0	1.57
Average Leaf Area (cm)	10.1	7.2	4.5	6.5	8.0	6.6	7.3	6.3	6.9**	0.09
Second Sampling Date										
Nonelongated Tillers:										
Tiller Number	3.3	4.6	5.3	7.0	6.6	3.6	5.3	6.3	6.8**	2.29
Whole Tiller Weight (gm)	0.14	0.07	0.06	0.05	0.05	0.05	0.02	0.03	0.07**	0.040
Leaf Number	3.2	2.8	2.3	2.4	2.3	2.3	1.2	2.1	2.5	0.52
Leaf Area (cm)	20.6	10.6	9.6	7.4	8.3	7.9	4.3	6.4	11.5**	0.46
Average Leaf Area (cm)	6.1	3.5	2.9	2.7	2.9	2.8	1.4	2.3	3.9**	1.19
Standard Leaf Weight (gm/cm)	6.3	6.7	5.0	7.3	5.7	6.0	2.3	4.0	5.8*	2.11

Table 2. Continued.

Parents	B40	B42	UA9	UA12	UA5	UA6	UA10	43	EXP. MEAN	STD. ERR.
Elongated Tillers:										
Tiller Number	8.3	17.3	26.6	26.3	22.6	19.3	23.0	12.6	18.1**	5.07
Whole Tiller Weight (gm)	0.62	0.56	0.50	0.43	0.53	0.49	0.49	0.31	0.51**	0.089
Leaf Number	4.8	4.9	4.9	4.4	4.6	4.9	4.9	4.6	4.9	0.45
Leaf Area (cm)	62.4	51.2	46.2	35.8	44.8	35.1	41.8	28.6	45.8**	0.67
Leaf Weight (gm)	0.35	0.29	0.27	0.23	0.27	0.26	0.26	0.15	0.27**	0.044
Standard Leaf Weight (mg/cm)	5.0	5.7	5.7	6.3	6.0	8.0	5.7	5.7	5.7**	0.73
Average Leaf Area (cm)	11.8	10.2	9.4	7.9	9.6	7.0	7.6	6.0	9.2**	1.16
Stem Length (cm)	30.3	33.3	38.0	24.3	28.3	33.3	29.3	29.6	31.0**	0.68
Stem Area (cm)	6.8	6.9	6.6	5.0	6.8	5.8	7.5	4.6	6.5**	0.11
Stem Weight (gm)	0.26	0.27	0.23	0.19	0.25	0.23	0.22	0.15	0.24**	0.049
Leaf to Stem Ratio	1.2	1.0	1.2	1.2	1.1	1.3	1.0	1.0	1.1	0.18
Headed Tillers:										
Tiller Number	2.6	3.6	1.6	4.0	2.3	7.3	7.0	12.3	4.8**	3.47
Whole Tiller Weight (gm)	1.18	0.56	0.22	0.41	0.59	0.81	0.60	0.79	0.61**	0.24
Leaf Number	3.9	3.7	2.0	3.9	2.7	5.6	4.1	5.8	3.6**	1.26
Leaf Area (cm)	79.5	50.4	19.4	30.7	38.0	61.3	43.0	51.8	43.1**	1.60
Leaf Weight (gm)	0.64	0.27	0.11	0.22	0.27	0.37	0.28	0.34	0.29**	0.122
Standard Leaf Weight (gm/cm)	7.7	3.7	2.0	5.3	3.7	6.3	4.7	6.7	4.6	1.88
Average Leaf Area (cm)	18.9	8.9	3.1	5.6	6.7	11.0	6.9	8.9	8.04**	3.08
Stem Length (cm)	30.0	21.0	13.3	17.6	18.3	35.6	25.0	40.6	23.5**	8.99
Stem Area (cm)	10.6	7.0	3.3	4.6	6.3	9.8	10.6	10.5	7.2**	0.26
Stem Weight (gm)	0.54	0.29	0.11	0.19	0.31	0.43	0.31	0.44	0.32**	0.126
Leaf to Stem Ratio	1.1	0.6	0.3	0.8	0.4	0.8	0.5	0.7	0.64	0.28

Table 2. Continued.

Parents	B40	B42	UA9	UA12	UA5	UA6	UA10	43	EXP. MEAN	STD. ERR.
Third Sampling Date										
Nonelongated Tillers:										
Tiller Number	0.6	1.3	1.0	1.3	0.6	1.3	0.3	1.6	0.9**	0.65
Whole Tiller Weight (gm)	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.01**	0.013
Leaf Number	0.4	1.0	0.6	0.9	0.3	0.9	0.4	1.7	0.8	0.54
Leaf Area (cm)	2.1	4.1	2.8	2.8	1.5	2.5	1.8	5.3	3.2	0.23
Leaf Weight (gm)	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.01**	0.013
Standard Leaf Weight (mg/cm)	2.0	3.0	4.3	5.7	3.7	5.0	3.0	4.0	2.3	0.50
Average Leaf Area (cm)	0.8	2.3	1.1	0.9	0.7	0.9	0.6	2.0	1.2	0.91
Elongated Tillers:										
Tiller Number	2.0	5.6	13.0	17.6	5.0	8.6	9.6	6.0	7.0**	3.78
Whole Tiller Weight (gm)	0.12	0.24	0.50	0.47	0.36	0.45	0.26	0.28	0.40	0.173
Leaf Number	3.1	4.5	6.0	5.8	4.1	6.1	4.3	5.5	5.1	0.93
Leaf Area (cm)	20.5	36.4	54.0	45.3	36.7	40.7	32.8	33.6	41.1	1.17
Leaf Weight (gm)	0.06	0.12	0.23	0.25	0.17	0.20	0.12	0.14	0.19	0.065
Standard Leaf Weight (mg/cm)	1.0	2.7	2.0	2.3	1.0	2.3	0.7	3.3	4.1	1.45
Average Leaf Area (cm)	4.4	7.1	8.7	7.4	6.4	6.2	5.2	6.0	6.9	0.14
Stem Length (cm)	19.0	38.0	52.0	38.3	34.0	41.6	31.0	39.6	40.1**	8.42
Stem Area (cm)	2.0	4.7	6.7	5.5	4.5	5.3	4.1	3.8	5.4	0.197
Stem Weight (gm)	0.54	1.26	2.64	2.27	1.95	2.45	1.46	1.44	2.16	1.190
Leaf to Stem Ratio	0.9	1.1	0.9	1.2	0.7	1.0	0.7	1.0	1.0	0.34

Table 2. Continued.

Parents	B40	B42	UA9	UA12	UA5	UA6	UA10	43	EXP. MEAN	STD. ERR.
Headed Tillers:										
Tiller Number	16.3	17.6	18.0	19.6	19.6	21.3	21.0	20.3	18.3**	3.80
Whole Tiller Weight (gm)	2.32	1.88	1.20	1.55	2.23	1.57	1.42	1.54	1.80**	0.237
Leaf Number	4.7	5.2	5.2	6.0	5.4	5.8	5.3	4.9	5.2**	0.36
Leaf Area (cm)	86.0	78.5	58.1	50.1	80.8	63.2	61.0	52.7	70.4**	0.86
Leaf Weight (gm)	0.48	0.39	0.29	0.29	0.46	0.35	0.29	0.26	0.38**	0.048
Standard Leaf Weight (mg/cm)	5.7	5.0	5.0	5.7	5.3	5.7	4.7	5.0	5.3**	0.50
Average Leaf Area (cm)	18.2	14.0	11.0	8.9	14.7	10.7	11.2	10.6	13.2**	0.13
Stem Length (cm)	87.6	97.0	81.3	72.0	93.6	85.3	91.3	91.6	90.5**	5.92
Stem Area (cm)	27.4	26.8	16.1	14.1	26.3	18.7	19.8	20.4	22.3**	0.25
Stem Weight (gm)	1.41	1.21	0.71	0.65	1.42	0.96	0.89	0.96	1.11**	0.163
Head Area (cm)	18.0	11.8	8.1	8.7	12.8	10.0	9.4	10.7	11.8**	0.17
Head Weight (gm)	0.42	0.28	0.19	0.20	0.35	0.25	0.23	0.30	0.31**	0.105
Leaf to Stem Ratio	0.3	0.3	0.4	0.4	0.3	0.3	0.3	0.2	0.3**	0.07
Fourth Sampling Date										
Nonelongated Tillers:										
Tiller Number	6.6	11.0	13.6	24.3	16.0	16.3	9.0	22.0	14.5**	3.81
Whole Tiller Weight (gm)	0.08	0.06	0.08	0.07	0.08	0.06	0.06	0.07	0.08	0.020
Leaf Number	2.7	2.7	2.9	2.8	2.6	2.6	2.9	2.9	2.8	0.27
Leaf Area (cm)	16.5	13.1	14.4	9.5	14.7	10.9	17.1	15.5	15.7*	0.43
Standard Leaf Weight (mg/cm)	4.7	4.0	4.7	6.3	3.7	5.3	3.7	4.3	5.4**	0.83
Average Leaf Area (cm)	24.1	19.3	19.5	13.1	22.4	16.6	23.2	19.8	21.5*	0.47

Table 2. Continued.

Parents	B40	B42	UA9	UA12	UA5	UA6	UA10	43	EXP. MEAN	STD. ERR.
Elongated Tillers:										
Tiller Number	10.3	16.6	18.3	15.6	15.3	16.0	25.0	12.0	13.5**	4.52
Whole Tiller Weight (gm)	0.34	0.26	0.25	0.16	0.23	0.25	0.30	0.19	0.26**	0.04
Leaf Number	3.8	3.9	4.3	3.8	3.5	3.8	4.6	3.9	3.9**	0.39
Leaf Area (cm)	52.9	43.7	34.4	20.3	34.4	31.7	52.6	33.9	37.6**	0.68
Leaf Weight (gm)	0.26	0.18	0.17	0.12	0.16	0.17	0.20	0.14	0.18**	0.031
Standard Leaf Weight (mg/cm)	5.0	4.7	6.0	7.7	5.7	6.3	4.3	5.0	4.7**	0.65
Average Leaf Area (cm)	55.2	44.0	32.5	21.9	32.6	32.7	44.7	34.4	36.5**	0.60
Stem Length (cm)	59.0	63.6	85.0	45.0	59.6	68.3	97.0	54.6	66.8**	12.35
Stem Area (cm)	13.1	11.9	11.3	5.5	10.7	9.9	17.3	8.5	11.3**	0.20
Stem Weight (gm)	0.35	0.29	0.29	0.14	0.26	0.28	0.41	0.18	0.30**	0.076
Leaf to Stem Ratio	3.0	2.6	2.5	3.5	2.2	2.5	2.0	3.1	2.7**	0.62
Headed Tillers:										
Tiller Number	0.6	0.3	1.0	0	0	0.3	1.6	0.3	0.5	0.76
Whole Tiller Weight (gm)	0.15	0.05	0.11	0	0	0.04	0.23	0.13	0.09	0.099
Leaf Number	1.6	0.7	1.5	0	0	0.7	3.0	1.7	1.0	1.01
Leaf Area (cm)	15.2	4.4	14.9	0	0	4.6	35.0	20.0	11.2	1.14
Leaf Weight (gm)	0.10	0.03	0.06	0	0	0.02	0.14	0.08	0.059	0.06
Standard Leaf Weight (mg/cm)	0.50	0.43	0.10	0	0	0.13	0.23	0.13	0.12	0.172
Average Leaf Area (cm)	12.6	4.4	9.9	0	0	3.7	25.0	16.1	8.8	0.90
Stem Length (cm)	21.6	9.3	29.3	0	0	9.0	58.0	26.0	18.5	18.96
Stem Area (cm)	6.7	1.6	0.6	0	0	2.3	15.0	6.9	6.0	7.99
Stem Weight (gm)	0.20	0.07	0.17	0	0	0.05	0.03	0.20	0.15	0.156
Leaf to Stem Ratio	0.6	0.3	0.4	0	0	0.3	0.8	0.6	0.3	0.48

** significant at 1%, * significant at 5%.

Table 8. Simple correlations between tiller characteristics, presenting the first sampling date above the diagonal, and the second sampling date below the diagonal. df=191 all correlations shown significant at 1%.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1. Nonelongated tiller number				-0.32						-0.28			-0.32						-0.37								
2. Elongated tiller number	0.30																										
3. Headed tiller number																											
4. Individual nonelongated tiller weight		-0.25	-0.28				0.34			0.77						0.31			0.76								
5. Individual elongated tiller weight	-0.30		-0.37																								
6. Individual headed tiller weight	-0.44	-0.43	0.35																								
7. Leaf number per nonelongated tiller	0.38		-0.28	0.61						0.57			0.34			-0.20			0.21								
8. Leaf number per elongated tiller					0.44																						
9. Leaf number per headed tiller	-0.31	-0.31	0.62	-0.31		0.78	-0.26																				
10. Leaf area per nonelongated tiller	0.21		-0.26	0.84	0.21		0.70		-0.31				0.77						0.91								
11. Leaf area per elongated tiller	-0.24		-0.35	0.26	0.90			0.43		0.34																	
12. Leaf area per headed tiller	-0.42	-0.39	0.39			0.95			0.82																		
13. Leaf weight per nonelongated tiller		-0.25	-0.28				0.61		-0.31	0.84	0.26					0.31			0.76								
14. Leaf weight per elongated tiller	-0.29		-0.46	0.30	0.96			0.34	-0.23	0.29	0.88		0.30														
15. Leaf weight per headed tiller	-0.43	-0.41	0.28			0.97			0.73			0.91															
16. Nonelongated tiller standard leaf wt.				0.62			0.45			0.23			0.62														
17. Elongated tiller standard leaf weight			-0.23		0.22									0.31		0.22											
18. Headed tiller standard leaf weight	-0.35	-0.34	0.44			0.81			0.80			0.72			0.85												
19. Nonelongated tiller average leaf area	0.28			0.78			0.66		-0.27	0.93	0.30		0.78	0.23		0.28											
20. Elongated tiller average leaf area			-0.40	0.31	0.74				-0.27	0.37	0.85		0.31	0.77					0.39								
21. Headed tiller average leaf area	-0.40	-0.37	0.33			0.90			0.69			0.95			0.90			0.71									
22. Elongated tiller stem length											0.29						-0.21			0.26							
23. Headed tiller stem length	-0.34	-0.26	0.69	-0.21		0.76	-0.25		0.86			0.79	-0.21	-0.23	0.70			0.73			0.72	0.30					
24. Elongated tiller stem area	-0.30				0.79	0.20		0.53			0.80			0.67						0.61		0.37					
25. Headed tiller stem area	-0.41	-0.34	0.49			0.92	-0.26		0.85			0.93			0.86			0.74			0.86		0.84	0.21			
26. Elongated tiller stem weight	-0.29		-0.26		0.96			0.50			0.85			0.85						0.66		0.25		0.86			
27. Headed tiller stem weight	-0.42	-0.43	0.39			0.97			0.79			0.93			0.90			0.73			0.86		0.77		0.92		
28. Elongated tiller leaf to stem ratio		-0.27	-0.22	0.31			0.26			0.25			0.31			0.21	0.40		0.25			-0.22		-0.29		-0.28	
29. Headed tiller leaf to stem ratio	-0.31	-0.27	0.38			0.73			0.75			0.70			0.82			0.93			0.70		0.66		0.67		0.61

Table 4. Simple correlations between tiller characteristics, presenting the third sampling date above, and the fourth sampling date below the diagonal. df = 191, all correlations shown significant at 1%

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1. Nonelongated tiller number				0.54			0.72			0.59			0.54			0.20		0.21	0.63											0.32	
2. Elongated tiller number			0.23		0.37	-0.44		0.60		-0.23	0.51	-0.33		0.39	-0.40			-0.25	-0.24	0.41	-0.39	0.57	-0.24	0.38	-0.38	0.32	-0.42	-0.46	-0.24		
3. Headed tiller number					-0.22									-0.27				-0.29													
4. Individual nonelongated tiller weight		-0.51					0.80			0.87					0.23	0.51		0.26	0.81			-0.22	-0.24							0.31	
5. Individual elongated tiller weight	-0.53							0.56			0.71			0.88			0.51			0.65		0.60		0.59		0.96			0.30		0.44
6. Individual headed tiller weight	-0.28		0.64		0.34			-0.30	0.24			0.80			0.89			0.26			0.77	-0.22	0.50		0.85		0.92	0.83	0.60		
7. Leaf number per nonelongated tiller				0.61						0.87			0.80			0.38			0.82				-0.26							0.30	
8. Leaf number per elongated tiller		0.37			0.59	0.25					0.77	-0.24		0.65	-0.30		0.34			0.68	-0.33	0.78		0.58	-0.30	0.46	-0.27	-0.31			
9. Leaf number per headed tiller	-0.23	0.27	0.73		0.25	0.90		0.29				0.40			0.34										0.24		0.27				
10. Leaf area per nonelongated tiller		-0.36		0.86	0.22		0.58						0.87		0.22	0.22			0.94			-0.23	-0.25							0.30	
11. Leaf area per elongated tiller	-0.49		0.24		0.88	0.40		0.61	0.34	0.30				0.77				-0.25		0.93		0.74		0.75		0.60					
12. Leaf area per headed tiller	-0.27	0.21	0.66		0.31	0.93		0.27	0.94		0.41				0.88						0.91		0.34		0.81		0.77	0.65	0.28		
13. Leaf weight per nonelongated tiller		-0.51					0.61			0.86					0.23			0.26	0.81			-0.22	-0.24							0.31	
14. Leaf weight per elongated tiller	-0.55				0.97	0.29		0.57		0.21	0.89	0.25					0.62			0.73		0.56		0.59		0.73					0.27
15. Leaf weight per headed tiller	-0.28		0.60		0.32	0.98		0.25	0.88		0.37	0.90		0.27				0.30	0.23		0.82	-0.27	0.25		0.73		0.81	0.71	0.44		
16. Nonelongated tiller standard leaf weight										-0.31	-0.41								0.21												
17. Elongated tiller standard leaf weight								0.28		-0.35						0.50		0.27			-0.21	0.22				0.40				0.47	0.26
18. Headed tiller standard leaf weight	-0.21		0.46			0.63			0.60			0.48			0.67					-0.22		-0.32							0.33	0.25	0.27
19. Nonelongated tiller average leaf area		-0.35		0.77	0.26		0.31			0.94	0.36		0.77	0.26		-0.38	-0.39					-0.24	-0.21							0.29	
20. Elongated tiller average leaf area	-0.50		0.21		0.77	0.35		0.38	0.29	0.24	0.89	0.35		0.79	0.32	-0.41			0.33			0.68		0.69		0.54	0.74				
21. Headed tiller average leaf area	-0.25		0.67		0.27	0.92		0.22	0.93		0.36	0.98		0.22	0.89			0.50		0.33			0.30		0.78			0.70	0.33		
22. Elongated tiller stem length	-0.24	0.58	0.30		0.61	0.40		0.68	0.41		0.58	0.41		0.50	0.38					0.45				0.62		0.57	0.58	-0.31			
23. Headed tiller stem length	-0.21	0.29	0.80		0.24	0.89		0.27	0.95		0.34	0.91			0.84			0.57		0.30	0.91	0.43			0.62			0.32			-0.33
24. Stem area per elongated tiller	-0.44	0.33	0.28		0.84	0.41		0.63	0.37		0 85	0.41		0.75	0.39	-0.34			0.24	0.74	0.37	0.79	0.38			0.54	0.87				
25. Stem area per headed tiller			0.56			0.65			0.67			0.60			0.63			0.81		0.29	0.60	0.28	0.68	0.29				0.71	0.37		
26. Stem weight per elongated tiller	-0.43	0.23	0.23		0.91	0.40		0.54	0.32		0.75	0.36		0.79	0.37				0.22	0.63	0.32	0.72	0.32	0.86	0.24				0.38	-0.23	0.49
27. Stem weight per headed tiller	-0.27	0.20	0.68		0.36	0.96		0.26	0.90		0.41	0.93		0.29	0.91			0.56		0.37	0.92	0.42	0.92	0.43	0.66	0.42		0.74	0.26		-0.32
28. Head area			0.41		0.22	0.50			0.42		0.22	0.44			0.43			0.22			0.49	0.28	0.52	0.27	0.32	0.25	0.53		0.57		
29. Head weight			0.31			0.35			0.23			0.27			0.27						0.33		0.32				0.35	0.70			0.63
30. Elongated tiller leaf to stem ratio		-0.26																				-0.38	0.20	-0.31		-0.41					
31. Headed tiller leaf to stem ratio			0.48			0.90			0.73			0.67			0.76			0.62			0.71	0.21	0.65		0.52		0.58	0.23			

Table 5. Tiller characters included in multiple regression equations for individual nonelongated tiller weight, n=192.

Characters	Regression Coefficient	Standardized Regression Coefficient
First Sampling Date		
Leaf area per nonelongated tiller	0.063***	0.826
Nonelongated tiller standard leaf weight	11.427***	0.455
Nonelongated tiller number	-0.0003***	-0.099
Intercept	-0.058	
R^2	0.820***	
Second Sampling Date		
Leaf area per nonelongated tiller	0.071***	0.863
Nonelongated tiller standard leaf weight	10.595***	0.523
Leaf number per nonelongated tiller	-0.020***	-0.249
Elongated tiller number	-0.0005***	-0.078
Leaf number per headed tiller	-0.0018**	-0.058
Intercept	0.002	
R^2	0.939****	
Third Sampling Date		
Leaf area per nonelongated tiller	0.057***	0.924
Nonelongated tiller standard leaf weight	1.039***	0.362
Headed tiller standard leaf weight	3.333***	0.125
Leaf number per headed tiller	0.004***	0.121
Leaf number per nonelongated tiller	-0.004**	-0.169
Leaf area per headed tiller	-0.0007*	-0.065
Intercept	-0.035	
R^2	0.897***	
Fourth Sampling Date		
Leaf area per nonelongated tiller	0.038***	0.834
Nonelongated tiller standard leaf weight	6.261***	0.274
Elongated tiller number	-0.0006***	-0.168
Leaf number per nonelongated tiller	0.007**	0.099
Intercept	-0.023	
R^2	0.881***	

*** significant at 0.1%, ** significant at 1%, * significant at 5%.

Table 6. Tiller characters included in multiple regression equations for individual elongated tiller weight, n=192.

Characters	Regression Coefficient	Standardized Regression Coefficient
Second Sampling Date		
Leaf area per elongated tiller	0.102***	0.852
Elongated tiller standard leaf weight	52.309***	0.372
Elongated tiller leaf to stem ratio	-0.112***	-0.182
Stem area per elongated tiller	0.100***	0.118
Elongated tiller stem length	-0.001***	-0.064
Intercept	-0.159	
R^2	0.947***	
Third Sampling Date		
Leaf area per elongated tilller	0.086***	0.591
Elongated tiller standard leaf weight	51.946***	0.447
Headed tiller leaf to stem ratio	0.702***	0.308
Elongated tiller leaf to stem ratio	-0.110***	-0.225
Headed tiller stem length	0.003***	0.165
Headed tiller number	-0.003**	-0.094
Intercept	-0.586	
R^2	0.821***	
Fourth Sampling Date		
Leaf area per elongatted tiller	0.060***	0.860
Elongated tiller standard leaf weight	24.656***	0.287
Elongated tiller leaf to stem ratio	-0.013***	-0.167
Elongated tiller number	-0.002***	-0.190
Elongated tiller stem length	0.0005***	0.127
Intercept	-0.052	
R^2	0.900***	

*** significant at 0.1%, ** significant at 1%, * significant at 5%.

Table 7. Tiller characters included in multiple regression equations for individual headed tiller weight, n=192.

Characters	Regression Coefficient	Standardized Regression Coefficient
Second Sampling Date		
Leaf area per headed tiller	0.110***	0.732
Headed tiller standard leaf weight	93.215***	0.658
Headed tiller leaf to stem ratio	-0.328***	-0.344
Leaf number per headed tiller	-0.038***	-0.197
Stem area per headed tiller	0.168***	0.185
Headed tiller number	-0.005***	-0.069
Intercept	-0.032	
R^2	0.967***	
Third Sampling Date		
Stem area per headed tiller	0.208***	0.223
Head area	0.470***	0.330
Headed tiller standard leaf weight	169.673***	0.268
Leaf area per headed tiller	0.101***	0.361
Headed tiller stem length	0.008***	0.181
Intercept	-1.611	
R^2	0.920***	
Fourth Sampling Date		
Leaf area per headed tiller	0.069***	0.803
Headed tiller standard leaf weight	19.659***	0.335
Head area	0.352***	0.111
Stem area per headed tiller	-0.016***	-0.134
Intercept	0.0008	
R^2	0.933***	

*** significant at 0.1%, ** significant at 1%, * significant at 5%.

Table 8. Tiller characters included in multiple regression equations for nonelongated tiller number, n=192.

Characters	Regression Coefficient	Standardized Regression Coefficient
First Sampling Date		
Individual nonelongated tiller weight	-133.007***	-0.507
Leaf number per nonelongated tiller	11.243***	0.305
Nonelongated tiller standard leaf weight	1656.468***	0.252
Intercept	4.962	
R^2	0.194	
Second Sampling Date		
Individual headed tiller weight	-2.628***	-0.264
Leaf number per nonelongated tiller	1.967***	0.390
Leaf weight per elongated tiller	-13.453***	-0.288
Elongated tiller number	0.078**	0.171
Intercept	5.710	
R^2	0.405***	
Third Sampling Date		
Leaf number per nonelongated tiller	1.066***	0.840
Elongated tiller leaf to stem ratio	0.228*	0.114
Leaf area per nonelongated tiller	-2.560***	-0.850
Nonelongated tiller average leaf area	5.652***	0.712
Intercept	-0.061	
R^2	0.587***	
Fourth Sampling Date		
Leaf weight per elongated tiller	-61.931***	-0.474
Leaf number per elongated tiller	2.283*	0.209
Leaf number per headed tiller	-0.792*	-0.153
Leaf number per nonelongated tiller	3.868**	0.195
Elongated tiller number	0.180*	0.176
Stem area per elongated tiller	-4.289*	-0.223
Intercept	9.154	
R^2	0.424***	

*** significant at 0.1%, ** significant at 1%, * significant at 5%.

Table 9. Tiller characters included in multiple regression equations for elongated tiller number, n=192.

Characters	Regression Coefficient	Standardized Regression Coefficient
Second Sampling Date		
Individual headed tiller weight	-10.749***	-0.498
Individual nonelongated tiller weight	-39.677***	-0.299
Elongated tiller stem length	0.169***	0.204
Elongated tiller standard leaf weight	-1352.422**	-0.181
Intercept	30.531	
R^2	0.372***	
Third Sampling Date		
Leaf number per elongated tiller	2.086***	0.482
Head area	-4.999***	-0.296
Leaf area per nonelongated tiller	-3.022**	-0.171
Leaf number per headed tiller	1.406*	0.134
Intercept	-4.292	
R^2	0.492***	
Fourth Sampling Date		
Elongated tiller stem length	0.210***	0.592
Individual nonelongated tiller weight	-89.317***	-0.367
Leaf weight per elongated tiller	-68.292***	-0.533
Leaf area per elongated tiller	2.396***	0.401
Nonelongated tiller number	0.141**	0.143
Intercept	8.693	
R^2	0.629***	

*** significant at 0.1%, ** significant at 1%, * significant at 5%.

Table 10. Tiller characters included in multiple regression equations for headed tiller number, n=192.

Characters	Regression Coefficient	Standardized Regression Coefficient
Second Sampling Date		
Headed tiller stem length	0.376***	0.019
Leaf weight per elongated tiller	-31.335**	-0.501
Elongated tiller stem length	-0.174***	-0.340
Leaf weight per headed tiller	-10.870***	-0.411
Individual elongated tiller weight	13.932*	0.423
Elongated tiller standard leaf weight	-407.181*	-0.088
Intercept	8.271	
R^2	0.684***	
Third Sampling Date		
Headed tiller standard leaf weight	-2608.982***	-0.332
Leaf weight per elongated tiller	-26.660***	-0.405
Elongated tiller standard leaf weight	691.476**	0.237
Intercept	34.455	
R^2	0.186	
Fourth Sampling Date		
Headed tiller stem length	0.053***	1.324
Leaf area per headed tiller	-0.184*	-0.277
Stem weight per headed tiller	-1.388*	-0.283
Intercept	-0.063	
R^2	0.694***	

*** significant at 0.1%, ** significant at 1%, * significant at 5%.

Table 11. Simple correlations between tiller characters at four sampling dates and yield n=192, all correlations shown significant at 1%.

Tiller Characters	First Sampling date Yield Total	First Sampling date Yield 1st. Harvest	First Sampling date Yield 2nd. Harvest	Second Sampling date Yield Total	Second Sampling date Yield 1st. Harvest	Second Sampling date Yield 2nd. Harvest	Third Sampling date Yield Total	Third Sampling date Yield 1st. Harvest	Third Sampling date Yield 2nd. Harvest	Fourth Sampling date Yield Total	Fourth Sampling date Yield 1st. Harvest	Fourth Sampling date Yield 2nd. Harvest
Nonelongated tiller number	0.25	0.22	0.18	-0.22	-0.20		-0.24	-0.24				
Elongated tiller number										0.29		0.32
Headed tiller number				0.26	0.22	0.18	0.26		0.27			0.31
Individual nonelongated tiller weight				-0.24	-0.23		-0.29	-0.32				
Individual elongated tiller weight												0.23
Individual headed tiller weight				0.22	0.23							0.32
Leaf number per nonelongated tiller				-0.29	-0.29		-0.25	-0.25				
Leaf number per elongated tiller												0.22
Leaf number per headed tiller				0.26	0.27							0.34
Leaf area per nonelongated tiller							-0.26	-0.29				
Leaf area per elongated tiller										0.20		0.34
Leaf area per headed tiller				0.26	0.26							0.34
Leaf weight per nonelongated tiller				-0.24	-0.23		-0.29	-0.32				
Leaf weight per elongated tiller					-0.16							
Leaf weight per headed tiller				0.21	0.22							0.29
Nonelongated tiller standard leaf weight				-0.23	-0.23	-0.23						-0.26
Elongated tiller standard leaf weight				-0.28	-0.23	-0.22				-0.20		-0.24
Headed tiller standard leaf weight					0.18		-0.23		-0.25			0.18
Nonelongated tiller average leaf area							-0.25	-0.29				
Elongated tiller average leaf area												0.32
Headed tiller average leaf area				0.23	0.22							
Elongated tiller stem length				0.27	0.19	0.25	0.20	0.18		0.32		0.46
Headed tiller stem length				0.36	0.34	0.23	0.44	0.32	0.40			0.37
Stem area per elongated tiller				0.26		0.26				0.25		0.42
Stem area per headed tiller				0.34	0.33	0.21			0.21			0.30
Stem weight per elongated tiller												0.30
Stem weight per headed tiller				0.21	0.24							0.35
Elongated tiller leaf to stem ratio					-0.25					-0.27		0.38
Headed tiller leaf to stem ratio							-0.19		-0.18			

Table 12. Simple correlations between sward characters and yield n=192, all correlations shown significant at 1%.

	Total Harvest Yield	First Harvest Yield	Second Harvest Yield	Mean Height	First Harvest Height	Second Harvest Height	Spread
First Harvest Yield	0.861						
Second Harvest Yield	0.745	0.301					
Mean Height	0.527	0.310	0.581				
First Harvest Height	0.483	0.408	0.371	0.885			
Second Harvest Height	0.448		0.657	0.882	0.560		
Vigor	0.526	0.465	0.374	0.581	0.617	0.409	0.236

Table 13. Stepwise multiple regression analysis with first harvest yield used as the dependent variable, n=192.

Characters	Regression Coefficient	Standardized Regression Coefficient
First Sampling Date		
Vigor	0.120***	0.282
Nonelongated tiller number	0.007***	0.370
Height at first harvest	0.007***	0.234
Spread	0.093*	0.200
Leaf area per nonelongated tiller	0.060	0.139
Intercept	-0.244	
R^2	0.354**	
Second Sampling Date		
Vigor	0.150***	0.352
Headed tiller stem length	0.003**	0.156
Leaf number per nonelongated tiller	-0.074**	-0.184
Elongated tiller standard leaf weight	-40.536*	-0.147
Intercept	1.292	
R^2	0.306**	
Third Sampling Date		
Vigor	0.136***	0.321
Individual nonelongated tiller weight	-3.180***	-0.211
Height at first harvest	0.006*	0.192
Leaf weight per headed tiller	-0.427*	-0.145
Intercept	0.682	
R^2	0.320**	
Fourth Sampling Date		
Vigor	0.163***	0.384
Nonelongated tiller number	0.007**	0.181
Height at first harvest	0.007**	0.227
Headed tiller number	-0.045*	-0.158
Individual nonelongated tiller weight	-1.350	-0.130
Intercept	0.295	
R^2	0.320**	

*** significant at 0.1%, ** significant at 1%, * significant at 5%.

Table 14. Stepwise multiple regression analysis with first harvest yield used as the dependent variable and sward characters deleted, n=192.

Characters	Regression Coefficient	Standardized Regression Coefficient
First Sampling Date		
Nonelongated tiller number	0.006***	0.282
Leaf area per elongated tiller	0.085**	0.197
Intercept	1.091	
R^2	0.087	
Second Sampling Date		
Headed tiller stem length	0.005***	0.245
Leaf number per nonelongated tiller	-0.095***	-0.236
Elongated tiller standard leaf weight	-52.761**	-0.191
Intercept	1.906	
R^2	0.198*	
Third Sampling Date		
Individual nonelongated tiller weight	-3.014**	-0.200
Headed tiller stem length	0.012***	0.426
Stem weight per headed tiller	-0.254**	-0.265
Intercept	0.672	
R^2	0.209*	
Fourth Sampling Date		
Elongated tiller number	0.008**	0.201
Headed tiller number	-0.043*	-0.151
Intercept	1.389	
R^2	0.049	

*** significant at 0.1%, ** significant at 1%, * significant at 5%.

Table 15. Stepwise multiple regression analysis with second harvest yield used as the dependent variable, n=192.

Characters	Regression Coefficient	Standardized Regression Coefficient
First Sampling Date		
Height at second harvest	0.016***	0.655
Nonelongated tiller number	0.005***	0.306
Vigor	0.041*	0.128
Intercept	-0.078	
R^2	0.536***	
Second Sampling Date		
Height at second harvest	0.016***	0.669
Elongated tiller number	0.007***	0.255
Headed tiller number	0.008***	0.178
Intercept	0.044	
R^2	0.515***	
Third Sampling Date		
Height at second harvest	0.014***	0.602
Headed tiller number	0.008***	0.215
Elongated tiller number	0.006**	0.153
Vigor	0.046*	0.141
Intercept	-0.057	
R^2	0.510***	
Fourth Sampling Date		
Height at second harvest	0.016***	0.658
Elongated tiller leaf to stem ratio	-0.046***	-0.204
Nonelongated tiller number	0.007***	0.246
Headed tiller number	0.037***	0.171
Intercept	0.223	
R^2	0.554***	

*** significant at 0.1%; ** significant at 1%; * significant at 5%.

Table 16. Stepwise multiple regression analysis with second harvest yield used as the dependent variable and sward characters deleted, n=192.

Characters	Regression Coefficient	Standardized Regression Coefficient
First Sampling Date		
Nonelongated tiller number	0.003**	0.239
Leaf area per nonelongated tiller	0.059*	0.178
Intercept	0.847	
R^2	0.065	
Second Sampling Date		
Stem area per elongated tiller	0.674***	0.530
Individual elongated tiller weight	-0.438*	-0.292
Headed tiller stem length	0.005**	0.348
Stem weight per headed tiller	-0.307*	-0.264
Intercept	0.853	
R^2	0.186	
Third Sampling Date		
Headed tiller stem length	0.007**	0.351
Number of headed tillers	0.006*	0.166
Headed tiller standard leaf weight	-44.031*	-0.144
Intercept	0.503	
R^2	0.225*	
Fourth Sampling Date		
Elongated tiller stem length	0.004***	0.384
Elongated tiller standard leaf weight	-53.453***	-0.228
Elongated tiller leaf to stem ratio	-0.037*	-0.166
Headed tiller number	0.030*	0.140
Intercept	1.153	
R^2	0.343***	

*** significant at 0.1%; ** significant at 1%; * significant at 5%.

Table 17. Mean Square values for general and specific combining ability and heritabilities for sward and tiller characters in bromegrass progenies, 1975.

Characters	Combining Ability		Reciprocal	Heritability	
	General	Specific	Effects	Broad Sense	Narrow Sense
Sward Characters					
Yield (gm/plot):					
Total	0.239**	0.054	0.042	0.48	0.377
Second harvest	0.091**	0.010	0.013	0.54	0.54
Height (cm):					
Mean	190.68**	24.56**	15.69*	0.78	0.56
First	166.51**	32.94**	20.54	0.65	0.43
Second	236.47**	24.39**	17.96	0.75	0.61
Spread	12.05	18.30**	12.89	0.41	0.39
Vigor	0.605*	0.250*	0.113	0.64	0.21
Tiller Characters					
First Sampling Date					
Nonelongated tillers:					
Tiller number	310.75**	44.432	51.46	0.54	0.49
Whole tiller wt. (gm)	0.005**	0.001**	0.001	0.74	0.37
Leaf number	0.065	0.057*	0.033	0.33	0.02
Leaf area (gm)	1.004**	0.177**	0.086	0.72	0.47
Second Sampling Date					
Nonelongated tillers:					
Tiller number	17.82*	5.60**	4.16	0.59	0.28
Whole tiller wt. (gm)	0.003**	0.001**	0.0009	0.52	0.22
Leaf area (cm)	0.752*	0.229**	0.095	0.62	0.30
Stand. leaf wt.(mg/cm)	0.940**	0.254	0.231	0.42	0.33
Average leaf area (cm)	0.049*	0.017**	0.007	0.64	0.26
Elongated tillers:					
Tiller number	124.09**	16.94	16.50	0.60	0.51
Whole tiller wt. (gm)	0.057**	0.007**	0.003	0.73	0.55
Leaf area (cm)	4.965**	0.412**	0.245	0.79	0.67
Leaf weight (gm)	0.018**	0.002**	0.0009	0.78	0.61
Stand. leaf wt.(mg/cm)	0.160**	0.032	0.026	0.38	0.25
Average leaf area (cm)	0.201**	0.015**	0.163**	0.81	0.67
Stem length (cm)	174.44	33.91*	22.29	0.40	0.17
Stem area (cm)	0.054**	0.010*	0.004	0.59	0.43
Stem weight (gm)	0.011**	0.002*	0.001	0.64	0.44
Leaf to stem ratio	0.055**	0.012	0.016	0.30	0.30

Table 17 Continued.

Characters	Combining Ability General	Combining Ability Specific	Reciprocal Effects	Heritability Broad Sense	Heritability Narrow Sense
Headed tillers:					
Tiller number	37.369**	6.22	5.08	0.46	0.45
Whole tiller wt. (gm)	0.248**	0.034	0.035	0.56	0.51
Leaf number	4.013**	1.17	1.07	0.46	0.29
Leaf area (cm)	9.951**	1.74	1.65	0.55	0.44
Leaf weight (gm)	0.064**	0.008	0.008	0.57	0.52
Average leaf area (cm)	0.460**	0.066	0.051	0.62	0.51
Stem length (cm)	290.36**	58.75	34.81	0.55	0.41
Stem area (cm)	0.238*	0.050*	0.526*	0.53	0.38
Stem weight (gm)	0.061**	0.009	0.010	0.53	0.46
Leaf to stem ratio	0.107*	0.045	0.032	0.26	0.19
Third sampling Date					
Nonelongated tillers:					
Tiller number	0.73	0.351*	0.18	0.43	0.16
Whole tiller wt. (gm)	0.003*	0.001	0.001	0.74	0.37
Elongated tillers:					
Tiller number	38.71**	9.40	8.02	0.47	0.35
Leaf number	1.75**	0.40	0.38	0.45	0.39
Stand. leaf wt.(mg/cm)	0.369**	0.085	0.125	0.30	0.19
Stem length (cm)	150.58**	81.83**	30.70	0.56	0.14
Leaf to stem ratio	0.161*	0.063	0.064	0.39	0.34
Headed tillers:					
Tiller number	38.53**	11.23*	7.06	0.50	0.30
Whole tiller wt. (gm)	0.718**	0.067**	0.055	0.80	0.63
Leaf number	0.420**	0.063	0.086	0.46	0.46
Leaf area (cm)	10.05**	0.70**	0.484	0.82	0.70
Leaf weight (gm)	0.039**	0.002**	0.001	0.85	0.70
Stand. leaf wt.(mg/cm)	0.102**	0.009	0.016	0.35	0.25
Average leaf area (cm)	0.340**	0.015**	0.012	0.86	0.78
Stem length (cm)	142.60**	38.99**	35.95**	0.61	0.32
Stem area (cm)	0.830**	0.078**	0.056**	0.81	0.63
Stem weight (gm)	0.296**	0.029**	0.024**	0.78	0.62
Head area (cm)	0.373**	0.029**	0.024**	0.80	0.69
Head weight (gm)	0.021*	0.007	0.008	0.38	0.23
Leaf to stem ratio	0.008*	0.002	0.383*	0.30	0.23

Table 17 Continued.

Characters	Combining Ability General	Combining Ability Specific	Reciprocal Effects	Heritability Broad Sense	Heritability Narrow Sense
Fourth Sampling Date					
Nonelongated tillers:					
Tiller number	166.78**	13.94**	9.61	0.79	0.66
Leaf area (cm)	0.267*	0.094	0.124	0.22	0.22
Stand. leaf wt.(mg/cm)	0.260**	0.045	0.025	0.48	0.37
Average leaf area (cm)	0.423**	0.111	0.129	0.30	0.30
Elongated tillers:					
Tiller number	69.86**	16.25*	14.77	0.55	0.36
Whole tiller wt. (gm)	0.020**	0.001	0.001*	0.73	0.67
Leaf number	0.550**	0.129**	0.214*	0.52	0.33
Leaf area (cm)	4.216**	0.250	0.251	0.74	0.72
Leaf weight (gm)	0.009**	0.0006	0.0005	0.75	0.68
Stand. leaf wt.(mg/cm)	0.131**	0.017	0.032*	0.33	0.26
Average leaf area (cm)	3.099**	0.248	0.222	0.73	0.66
Stem length (cm)	846.68**	73.04	108.37	0.61	0.61
Stem area (cm)	0.372**	0.029	0.038**	0.73	0.65
Stem weight (gm)	0.038**	0.003	0.058**	0.65	0.59
Leaf to stem ratio	0.847*	0.341**	0.046**	0.44	0.19
Headed Tillers:					
Tiller number	1.207**	0.21	0.25	0.36	0.36
Whole tiller wt. (gm)	0.017**	0.002	0.006	0.32	0.32
Leaf number	1.988**	0.364	0.526	0.35	0.33
Leaf area (cm)	2.310**	0.416	0.793	0.31	0.31
Leaf weight (gm)	0.006**	0.0008	0.002	0.29	0.27
Average leaf area (cm)	1.259**	0.223	0.510	0.35	0.33
Stem length (cm)	802.48**	114.42	170.29	0.38	0.35
Stem weight (gm)	0.039**	0.006	0.015	0.28	0.27
Leaf to stem ratio	0.321**	0.091	0.164	0.42	0.39

** significant at 1%, * significant at 5%.

Table 18. General combining ability effects (g_i) for sward characters of bromegrass, 1975.

Clone	Total Yield	First Harvest Yield	Second Harvest Yield	Mean Height	Height at First Harvest	Height at Second Harvest	Vigor
B40	-3.64	-1.29	-2.26	3.4573	3.4339	3.4677	0.062
B42	-8.78	-6.72	-2.05	1.1135	1.4651	0.7656	0.000
UA9	11.78	3.65	8.09	0.3240	-0.5766	1.2281	0.083
UA12	-23.18	-7.72	-15.34	-7.4469	-6.6870	-8.1948	-0.458
UA5	8.72	4.96	3.66	0.8052	1.4714	0.1385	0.083
UA6	-2.95	-3.97	0.95	0.2177	-1.2391	1.6698	0.000
UA10	13.05	4.44	8.64	3.2948	3.0526	3.5406	0.187
43	4.99	6.65	-1.68	-1.7656	-0.9203	-2.6156	0.041
STD.ER. (g)	7.27	5.60	3.71	1.0913	1.4104	1.3140	0.107

Table 19a. Specific combining ability effects (s_i) for sward characters of bromegrass clones, 1975.
Total yield shown above the diagonal, mean height shown below the diagonal.

Clone	B40	B42	UA9	UA12	UA5	UA6	UA10	43
B40	-0.29	-0.11	-0.06	0.07	0.02	0.23	-0.03	0.17
	-5.17							
B42		0.19	0.01	-0.31	0.04	-0.16	0.03	0.29
	-3.81	-0.48						
UA9			-0.17	0.24	-0.13	0.11	-0.05	0.05
	-0.58	1.58	-1.43					
UA12				0.03	0.16	-0.11	0.19	-0.28
	1.61	-5.85	0.69	-3.39				
UA5					-0.09	-0.08	0.08	-0.01
	3.84	2.49	-1.78	3.95	-4.40			
UA6						0.22	-0.19	-0.02
	-0.14	1.17	4.18	1.38	-3.74	-5.15		
UA10							0.02	-0.05
	-0.55	0.68	-0.49	7.81	-0.67	0.41	-3.38	
43								-0.14
	4.81	4.21	-2.16	-6.21	0.31	1.89	-3.80	0.94

Total dry weight:

STD.ER. of the difference between the effects of two parent lines = 0.2520
STD.ER. of the difference between the effects of a parent line and a cross having that line as one parent = 0.2413
STD.ER. of the difference between the effects of a parent line and a cross not having that line as a parent = 0.2182
STD.ER. of the difference between effects of two crosses having one parent line in common = 0.1925
STD.ER. of the difference between effects of two crosses having no parent lines in common = 0.1782

Mean height:

STD.ER. of the difference between the effects of two parent lines = 3.7802
STD.ER. of the difference between the effects of a parent line and a cross having that line as one parent = 3.6193
STD.ER. of the difference between the effects of a parent line and a cross not having that line as a parent = 3.2738
STD.ER. of the difference between effects of two crosses having one parent line in common = 2.8872
STD.ER. of the difference between effects of two crosses having no parent lines in common = 2.6730

Table 19b. Specific combining ability effects (s_i) for sward characters of bromegrass clones, 1975.
Height at first harvest shown above the diagonal, height at second harvest shown below the diagonal.

Clone	B40	B42	UA9	UA12	UA5	UA6	UA10	43
B40	-4.17	-3.54	-2.58	4.35	3.08	-1.25	-0.88	5.00
	-6.19							
B42		-1.57	-0.40	-6.25	1.41	3.37	0.25	6.72
	-4.07	0.64						
UA9			-1.32	2.86	-2.79	5.00	0.37	-1.14
	1.43	3.58	-1.54					
UA12				-5.77	4.98	0.44	7.23	-7.87
	-1.11	-5.49	-1.45	-1.03				
UA5					-1.92	-5.12	0.49	-0.14
	4.63	3.58	-0.79	2.88				
UA6						-5.00	1.29	1.26
	0.93	-1.02	3.34	2.35	-2.39	-5.26		
UA10							-3.58	-5.19
	-0.26	1.10	-1.35	8.39	-1.85	-0.46	-3.17	
43								1.36
	4.64	1.67	-3.20	-4.53	0.80	2.52	-2.38	0.47

Height at first harvest:
STD.ER. of the difference between the effects of two parent lines = 4.8856
STD.ER. of the difference between the effects of a parent line and a cross having that line as one parent = 4.6776
STD.ER. of the difference between effects of a parent line and a cross not having that line as a parent = 4.2311
STD.ER. of the difference between effects of two crosses having one parent line in common = 3.7315
STD.ER. of the difference between effects of two crosses having no parent lines in common = 3.4547

Height at second harvest:
STD.ER. of the difference between the effects of two parent lines = 4.5520
STD.ER. of the difference between the effects of a parent line and a cross having that line as one parent = 4.3582
STD.ER. of the difference between effects of a parent line and a cross not having that line as a parent = 3.9421
STD.ER. of the difference between effects of two crosses having one parent line in common = 3.4766
STD.ER. of the difference between effects of two crosses having no parent lines in common = 3.2187

Table 19c. Specific combining ability effects (s_{i}) for sward characters of bromegrass clones, 1975.
First harvest yield shown above the diagonal,
second harvest yield shown below the diagonal.

Clone	B40	B42	UA9	UA12	UA5	UA6	UA10	43
B40	-0.08	-0.03	-0.03	-0.02	0.04	0.03	0.02	0.08
	-0.22							
B42		0.02	0.02	-0.16	0.06	-0.04	0.02	0.13
	-0.07	0.17						
UA9			-0.06	0.20	-0.06	0.02	-0.01	-0.02
	-0.03	0.00	-0.10					
UA12				-0.09	0.08	-0.01	0.04	-0.06
	0.09	-0.16	0.04	0.12				
UA5					-0.05	-0.01	0.08	-0.07
	-0.02	-0.01	-0.07	0.07	-0.03			
UA6						0.06	-0.02	-0.01
	0.20	-0.11	0.11	-0.10	-0.07	0.16		
UA10							0.08	- 0.04
	-0.03	0.02	-0.04	0.14	0.07	-0.16	0.01	
43								0.08
	0.09	0.15	0.08	-0.21	0.06	-0.01	-0.01	-0.15

First harvest yield:

STD.ER. of the difference between the effects of two parent lines = 0.1285
STD.ER. of the difference between the effects of a parent line and a cross having that line as one parent = 0.1231
STD.ER. of the difference between effects of a parent line and a cross not having that line as a parent = 0.1113
STD.ER. of the difference between effects of two crosses having one parent line in common = 0.0982
STD.ER. of the difference between effects of two crosses having no parent lines in common = 0.0909

Second harvest yield:

STD.ER. of the difference between the effects of two parent lines = 0.1940
STD.ER. of the difference between the effects of a parent line and a cross having that line as one parent = 0.1858
STD.ER. of the difference between effects of a parent line and a cross not having that line as a parent = 0.1680
STD.ER. of the difference between effects of two crosses having one parent line in common = 0.1482
STD.ER. of the difference between effects of two crosses having no parent lines in common = 0.1372

Table 19d. Specific combining ability effects (s_i) for sward characters of bromegrass clones, 1975.
Vigor shown below the diagonal.

Clone	B40	B42	UA9	UA12	UA5	UA6	UA10	43
B40	-0.35							
B42	-0.29	0.43						
UA9	-0.37	0.02	0.27					
UA12	0.33	-0.60	0.31	-0.31				
UA5	0.29	0.02	-0.22	0.14	0.27			
UA6	0.37	0.10	0.35	0.06	-0.64	-0.56		
UA10	-0.14	-0.08	-0.33	0.70	-0.00	0.08	0.06	
43	0.16	0.39	-0.02	-0.64	0.14	0.22	-0.29	0.02

Vigor:
STD.ER. of the difference between the effects of two parent lines = 0.3728
STD.ER. of the difference between the effects of a parent line and a cross having that line as one parent = 0.3570
STD.ER. of the difference between the effects of a parent line and a cross not having that line as a parent = 0.3229
STD.ER. of the difference between effects of two crosses having one parent line in common = 0.2848
STD.ER. of the difference between effects of two crosses having no parent in common = 0.2636

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